# THE PLANT DISEASE REPORTER

Issued By

PLANT DISEASE EPIDEMICS
and
IDENTIFICATION SECTION

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The Plant Disease Reporter is issued as a service to plant pathologists throughout the United States. It contains reports, summaries, observations, and comments submitted voluntarily by qualified observers. These reports often are in the form of suggestions, queries, and opinions, frequently purely tentative, offered for consideration or discussion rather than as matters of established fact. In accepting and publishing this material the Plant Disease Epidemics and Identification Section serves merely as an informational clearing house. It does not assume responsibility for the subject matter.

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# THE PLANT DISEASE REPORTER

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PLANT DISEASE EPIDEMICS AND IDENTIFICATION SECTION

Horticultural Crops Research Branch — Plant Industry Station, Beltsville, Maryland

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# A CHYTRID ATTACKING OOSPORES OF PERONOSPORA TABACINA

L. H. Person, G. B. Lucas, and W. J. Koch[1]

Blue mold of tobacco, caused by Peronospora tabacina Adam, has been a serious threat to tobacco plant production in southeastern United States since 1931. When the same plant bed sites are used each year, circumstantial evidence indicates that primary outbreaks of the disease may result from the germination of overwintering oospores. Although these oospores are frequently formed in great numbers in dead or dying leaves invaded by the blue-mold fungus, complete information is lacking concerning the environmental conditions that favor oospore germination, the method of germination and the manner by which oospores infect tobacco plants.

Various investigators have attempted to induce oospore germination (1, 2, 3, 4). Armstrong and Sumner (1) were unsuccessful in their efforts to germinate the oospores. Wolf et al. (4) exposed diseased leaves containing oospores to alternating cold and warm temperatures for about 6 months. At the end of that time an occasional oospore produced a germ tube when bits of these leaves were macerated and kept in drops of water on glass slides. Indirect evidence that oospores were responsible for infection was obtained by Person and Lucas by inoculating tobacco seedlings with water suspensions of bits of dead tobacco leaves containing oospores (2, 3). When this was done blue mold sometimes developed. Infection was secured on plants grown in a constant-temperature (18° C) room in the summer and fall when conidia of the blue-mold fungus were not being produced. Observations of the oospores used for inoculum indicated spherical, sessile sporangia, in which zoospores were produced, attached to the sides of the oospores. Initially it was thought that these were part of the oospores. However, it is unusual for oospores of the Peronosporaceae to form sessile sporangia and infection obtained upon inoculation of the tobacco seedlings using the method described above was erratic. Therefore, Dr. J. N. Couch[2] was asked to examine some of the oospores with attached sporangia. He indicated that the sporangia and zoospores possibly might belong to chytrids that were parasitizing the oospores. It appeared probable that the chytrids growing on the oospores came from chytrid-infested soil adhering to the tobacco leaves.

This note presents evidence as to the true nature of the sporangia attached to the oospores and the possible role played by chytrids in preventing germination of the oospores of P. tabacina.

To determine whether the zoospores were produced by the oospores of P. tabacina or by a chytrid, some of the oospores with attached sporangia were placed in water in Petri dishes along with pollen grains of sweetgum (Liquidambar styraciflua L.). In a few days unicellular thalli (sporangia) of a species of Phlyctochytrium, a soil-inhabiting chytrid that is known to parasitize algae and fungus spores, were seen attached to the pollen grains. The thalli had the same identifying characteristics (size, shape, number of discharge papillae and punctations of the wall) as the sporangia seen on Peronospora tabacina. These thalli produced many zoospores from which pure cultures of Phlyctochytrium were secured by making dilution plates with a zoospore suspension and later transplanting to potato-dextrose agar.

To prove that the Phlyctochytrium would grow on the oospores of Peronospora tabacina the following test was repeated three times. Bits of tobacco leaves containing oospores that had not come in contact with the ground were placed in sterilized water in Petri dishes. The plates were divided into two groups. To one group thalli of the chytrid grown in pure culture were added and the plates were incubated at room temperature. Two days later young developing sporangia of the chytrid were seen attached to the oospores; no chytrid thalli were observed on the oospores placed in Petri plates to which no chytrid inoculum had been added. Seven days after inoculation young developing chytrid sporangia, mature sporangia, and sporangia that had discharged zoospores were seen attached to many of the oospores in those plates containing chytrid inoculum. In addition many chytrid oospores were swimming in the water. No Phlyctochytrium sporangia or zoospores were observed in the dishes to which no chytrids had been added.

These data indicate that the manner by which the oospores of Peronospora tabacina normally germinate and initiate infection on tobacco still remains unknown. However, no satisfactory explanation is available as yet for the blue-mold infection that resulted when the oospores were used as inoculum on tobacco seedlings in the inoculation experiments described previously (2).

These findings also provide a possible explanation for some of the difficulty experienced in

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inducing germination of the oospores of P. tabacina. Little notice has been given to the possible role played by chytrids in biological control of fungi. Yet it is well established that chytrids are common soil inhabitants and frequently parasitize algae and fungus spores, including oospores of the Peronosporaceae. Primary infections of tobacco by P. tabacina in old plant beds usually occur only in a very few loci although the plant beds may be hundreds of square yards in area. These primary infections, few in number in old plant beds, probably result from oospore germination. Yet in the surface half inch of soil of infested plant beds there conceivably could be millions of oospores of P. tabacina released into the soil by decomposition of blue-mold infected leaves. The occurrence of only scattered foci of infection in any single plant bed could be explained in part by the fact that Phlyctochytrium and other chytrids may attack the oospores and prevent a high percentage of them from germinating.

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# AN ERIOPHYID MITE VECTOR OF THE PEACH-MOSAIC VIRUS

Norton S. Wilson, Laurence S. Jones, and L. C. Cochran[1,2]

## Abstract

An eriophyid mite of the genus Eriophyes, apparently an undescribed species, has been found to be a vector of the peach-mosaic virus. It has been found naturally infesting peach and certain species of plums. On peach it has been taken from beneath closely adhering bud scales, and on plum has been found also on rudimentary leaves of new growth. A total of 19 transmissions have been effected.

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An eriophyid mite found naturally infesting peach and plum has been shown to be a vector of the peach-mosaic virus. It is a member of the genus Eriophyes, probably undescribed; it is closely related to several other species of this genus occurring in southern California on rosaceous hosts. The mite was first collected on April 22, 1955, near Riverside, California, on mosaic-infected peach trees 5 years old, in an isolated test plot being maintained expressly because the site has furnished natural spread of peach mosaic at a rate equaling the maximum recorded in orchards in problem areas. The spread in this planting is considered to have been from peach to peach, since no plum or other stone-fruit trees were growing in the vicinity.

On peach trees the mite has been found only as a bud-infesting species, feeding and reproducing beneath closely adhering leaf-bud scales. The densest populations were in retarded buds in April, which had not yet expanded in leaf or shoot development. The mites were found to persist in findable numbers only as long as some basal scales remained tightly appressed, as was frequently the case on stunted spurs; when protective bud scales flared, the mites were no longer found, and it is presumed that they disseminate at that time. Transportation in air currents is their probable means of natural dissemination. In late summer the mites found on peach trees were only in retarded and stunted buds, which in southern California are common at this season. Such bud retardation is characteristic of the peach mosaic disease, and hence the persistence of the virus vector is favored in diseased trees.

The mite has been found infesting several species of plums, some of which are native to extensive areas of the country. On the plums the species has been found under scales of dormant and retarded buds, but the mites have also been found reproducing in leaf axils and among rudimentary leaves of expanding buds on vigorously growing shoots. The following species of plums, growing in a separate plot near Riverside, have been found infested: Chickasaw (Prunus angustifolia); hortulan (P. hortulana); Wild Goose or Pottawattamie (P. munsoniana); Mexican (P. mexicana); and myrobalan (P. cerasifera).

The successful transmission of the peach-mosaic virus by this mite came after more than 8000 tests with more than 150 species of insect and mite suspects. Particular emphasis was placed on all aphids and leafhoppers occurring on peach and associated orchard plants. The results of all experiments were negative except those with the mites reported here.

The initial transmission of the peach-mosaic virus was the result of a series of transfers of the mites from naturally infested, mosaic-diseased field peach and plum trees to 65 healthy, potted Rio Oso Gem peach seedlings in a greenhouse. Of these transfers 56 were from peach and 9 were from hortulan plum.

Seventeen of the 65 test peach trees have exhibited symptoms of peach mosaic; 16 of them received mites from infected peach and 1 from hortulan plum. As a confirmatory test of the presence of peach-mosaic virus, patch bark grafts were taken from 10 of 17 reacting trees and placed in other healthy peach seedlings; all the graft-inoculated trees developed typical symptoms of peach mosaic.

The transmission in the initial series of tests was accomplished by groups of unseparated adult and immature mites, 4 and 5 mites to each tree in 3 tests, 2 to 10 mites in 10 tests, 34 and 40 mites in 2 tests, and 50 and 60 mites in 2 tests.

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[1] N. S. Wilson and L. S. Jones are entomologists in the Entomology Research Branch, and L. C. Cochran is plant pathologist in the Horticultural Crops Research Branch, Agricultural Research Service, United States Department of Agriculture.

[2] Greenhouse space and test plots were provided by the California Agricultural Experiment Station and the California State Department of Agriculture; this assistance is gratefully acknowledged.

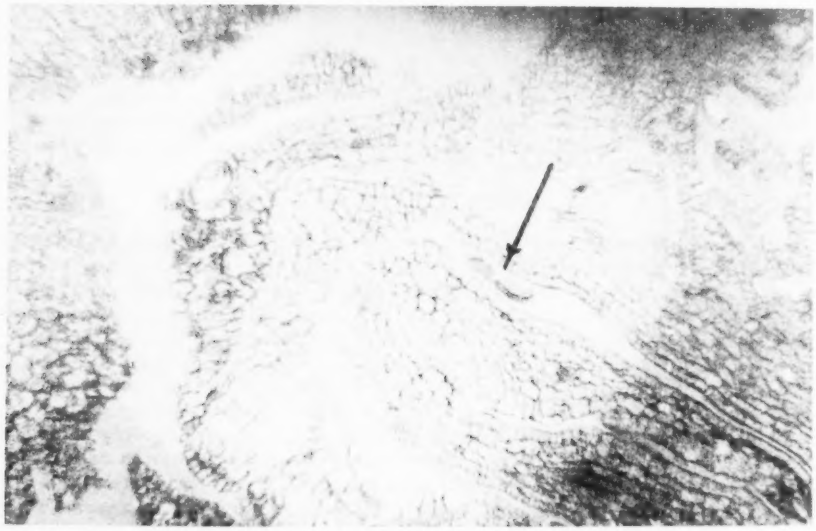

FIGURE 1. Left: Retarded leaf bud of peach in Jun with outer scales removed, exposing plant tissues and location of peach mosaic transmitting eriophyid mites (arrows). Right: Longitudinal section of unopened leaf bud of peach, showing the mite (arrow) in protected situation.

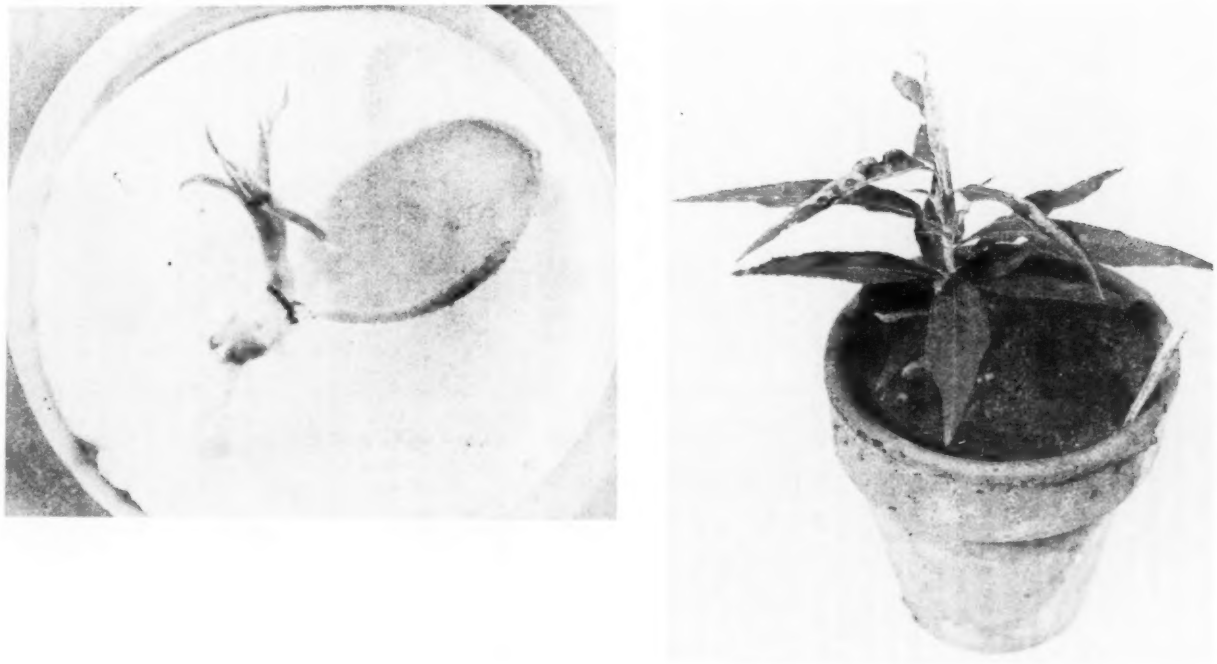

FIGURE 2. Left: Rio Oso Gem peach seedling with one cotyledon removed growing temporarily on moist filter paper in Stender dish; seedling about 1 inch high, one type of tree successfully used in transmission tests with Eriophyes sp. Right: Rio Oso Gem peach seedling showing peach mosaic symptoms resulting from inoculation by Eriophyes sp. This tree received 15 mites from an infected field tree when in stage illustrated on left.

In subsequent and more extensive new work two additional cases of transmission have been secured, one following the feeding of a single adult mite.

Peach mosaic symptoms appeared on the young peach trees after mite transfers to them in 14 to 20 days in 9 tests, in 20 to 30 days in 3 tests, in 31 to 60 days in 3 tests, and in about 100 days in 2 tests. Check trees which had received equivalent numbers of mites of this species from healthy peach and plum trees developed no symptoms.

The Rio Oso Gem peach seedling test trees were of three types: (a) newly germinated seedlings less than 3 inches tall and frequently under an inch with only rudimentary leaves, (b) new seedlings 3 to 12 inches tall, and (c) year-old whips emerging from dormancy. All the prompt reactions appeared in either group (a) or (c). It seems probable that more of the 65 original trees may show symptoms after a dormant period. In some earlier work to determine the time of year of natural spread of disease into young trees (Jones and Wilson 2), we found that in one season when 390 trees were exposed to spread the 23 trees that became infected showed symptoms the following spring; in a second season 445 trees were exposed and the 167 trees that became infected showed symptoms the next spring.

It has been found in pathological work in this location that field-plot trees graft-inoculated when just breaking dormancy usually show symptoms within 3 to 6 weeks, but trees that are in foliage when inoculated have a longer incubation period and often do not show symptoms until after a period of dormancy. In previous entomological work with potted trees in the greenhouse the time required between graft inoculations and symptom appearance was extremely variable and largely unpredictable. While symptoms appeared in some instances in 14 days, many of the trees showed no symptoms during the same season they were inoculated.

Peach mosaic disease is a continuing problem in peach growing in southern California, Colorado, Texas, and in restricted parts of Oklahoma and Arkansas (Hutchins et al. 1). After transmission by this Eriophyes mite had been determined, a brief collecting trip outside southern California was made, and the species was readily taken in mosaic-infected orchards in western Colorado, Arizona, and New Mexico in all the districts in which a search was made.

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# A DISEASE OF STRAWBERRY CAUSED BY A VIRUS FROM RED RASPBERRY

Edward K. Vaughan and Harold W. Wiedman[1]

## Summary

A mottle mosaic virus from red raspberry has been transferred by graftage to Fragaria vesca. Symptoms in the latter plant include shortened styles, enlarged ovaries, shortened filaments, sterile anthers, adherent green petals, enlarged and misshapened sepals, and the production of "runner plants" on the fruit spurs. No similar disease has been seen in the field, and it is presumed that this virus is not a factor in the yellows virus complex affecting commercial strawberries in the Pacific Northwest.

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Transmission of a virus from red raspberry (Rubus idaeus) to strawberry (Fragaria vesca, East Malling Strain) by graftage, has been reported in a previous paper (3). Production of disease in one species with a virus from another species or genus is now a familiar occurrence. The disease is described here in order to distinguish it from other virus diseases of strawberry, and because the fundamental changes in the morphology of the plant are unusual.

The virus, which previously has been transmitted experimentally from the Washington variety to Washington, Cuthbert, Canby and several seedling red raspberries, and to black raspberry seedlings, produces in these plants a mottle type of mosaic which, under Oregon conditions, appears first as a ring spot, particularly on the lower half of the plant, and later as a distinct foliage mottle (2) which is not restricted to any part of the plant. In most seasons in Oregon all symptoms, except a slight loss in vigor, disappear by mid-July and do not reappear until the following season.

In Fragaria vesca the first symptoms appeared 6 weeks after the grafts were made. A slight yellowish stippling or mottling appeared in the new leaves of the mother plants and soon, also, in the runner progeny. No other symptoms except loss of vigor were noted during the first season, and during this period the disease would probably have been diagnosed as mild crinkle or as a non-persistent virus.

The first flowers that developed the following season were different from the normal flowers of F. vesca. The styles were shorter with the total length reduced to not more than half the diameter of the ovary. The ovaries were reduced in number and greatly swollen, and were apparently sterile. Despite the presence of normal plants with pollen-producing anthers, as well as bees, in the greenhouse, none of the affected flowers produced fruit.

The stamen filaments, which in a normal flower are 2 to 3 mm in length, were reduced to not more than 0.5 mm or were entirely lacking, and the anthers contained no pollen.

The five calyx lobes were greatly enlarged and leaf-like, but the five bracteoles remained nearly normal.

The five (sometimes six) obovate petals, that normally are white, were at least partially green, reduced in size, partly folded and pointed (Figure 1, B). In some cases the entire petal was green and in others only the tip. This symptom at first suggested a relationship with the Green Petal disease described by Posnette (1) in England. The other symptoms were, however, quite different. Three months after the first observations were made, the petals were still adhering to the receptacles, and were still green. Flowers produced later in the season appeared quite normal but were sterile. All infected plants were more or less stunted and steadily declined in vigor.

The infected plants produced "runner plants" which arose at the nodes of the fruit spurs. When pegged down, they developed roots but were not vigorous. None of the affected plants produced any stolons, but as many as 16 runner plants were present at one time on the peduncles of a single plant.

No similar disease has been seen in the field, although red raspberries and strawberries are frequently grown in adjacent fields. It is doubtful that infected plants would live through the winter. If they did, most growers would either destroy, or call to the attention of the County Agent, any plants which were so severely affected and did not produce any fruit. It is presumed, therefore, that this virus is not a factor in the yellows virus complex affecting com-

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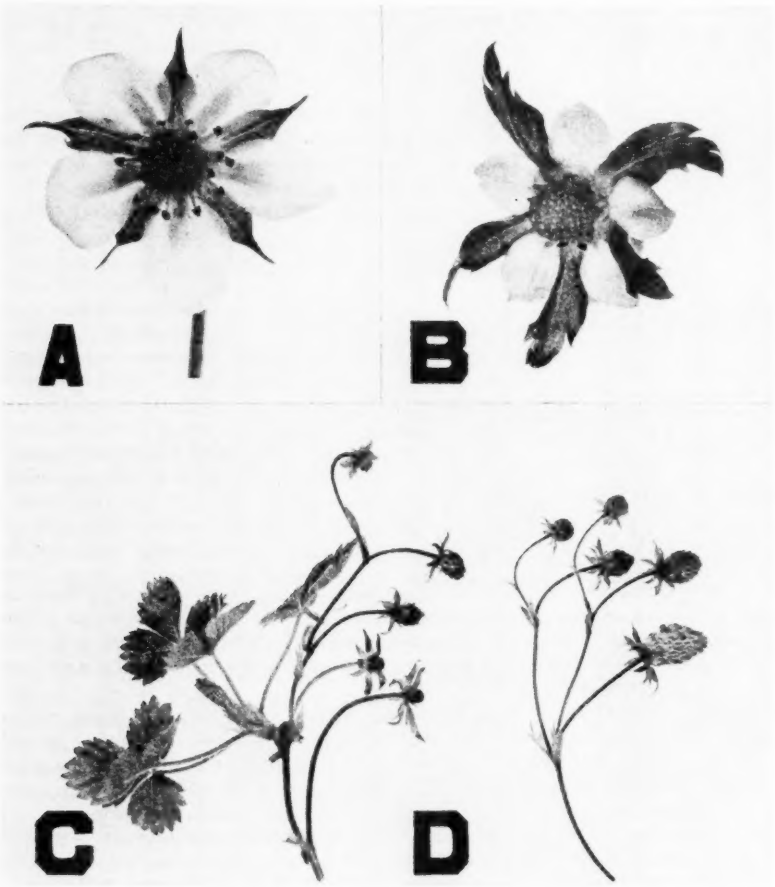


FIGURE 1. A -- Normal flower of Fragaria vesca, x about 1 1/2. B -- Flower from F. vesca plant affected with virus from red raspberry. C -- Fruit spur from infected plant showing abortive fruits and production of a "runner plant". D -- Fruit spur from a normal F. vesca plant.

mercial strawberries in the Pacific Northwest.

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# THE OCCURRENCE OF TWO DISTINCT TYPES OF CORN STUNT IN MEXICO

Karl Maramorosch

## Summary

A field survey revealed the presence of two distinct types of corn stunt disease in Mexico. The Rio Grande type, not previously found in Mexico, corresponds to the stunt of Texas and California. The Mesa Central type, not known to occur in the United States, differs from the Rio Grande type by its chlorotic markings, severity of stunting and amount of red coloring. Dalbulus maidis efficiently transmitted both types of the causative virus to several varieties of corn. The symptoms characteristic of each type were consistently reproduced irrespective of of the variety used.

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Corn stunt has been reported from California (2), Texas (1), and Mexico (5). The leafhopper vector of corn stunt virus, Dalbulus maidis DeL. & W., was discovered by Kunkel (3). In addition to D. maidis the related corn leafhopper D. elimatus DeL. & W. was found to be an important vector in Mexico (5). The similarity of symptoms and the identity of the vector D. maidis, as well as the relative proximity of areas from which the disease has been reported, led to the conclusion that the stunt prevalent in the southern part of the United States and the stunt in Mexico were identical. However, observations made in a greenhouse at the Rockefeller Institute in New York over a period of 6 years gave reasons for believing that the corn stunt in the two countries differed in several aspects. In order to elucidate this problem a field survey of corn stunt was carried out in Mexico during the summer of 1955[1].

The results of the survey revealed the existence of two distinct types of corn stunt in Mexico. The two types have been designated as the Rio Grande and the Mesa Central, because the first was known and originally described from the Rio Grande valley, whereas the second was found to be the typical corn stunt on the Mexican plateau. Descriptions of the two types and preliminary observations on their respective distributions and vector transmission follow.

The Rio Grande type was previously reported only from the United States. Early symptoms are characterized by small chlorotic spots appearing at the bases of newly developed leaves. These spots vary in area from pin points to elongated stripes of considerable dimensions. Successive leaves are affected to an increasing degree and finally fully chlorotic leaves develop. At first the chlorotic stripes are not continuous but are composed of separated spots which only later combine into long streaks (Fig. 1 A). Upper internodes are much shortened and an abnormally large number of chlorotic secondary shoots appear in the axils of leaves and along ear-bearing branches, as illustrated in Fig. 2 B. A tendency for diseased leaves to become slightly tinged with red, and for the diseased stalks to become reddish was noted under greenhouse conditions (4).

The Mesa Central type, until recently considered as the only kind of corn stunt occurring in Mexico, differs from the Rio Grande type mainly in chlorotic markings, severity of stunting and amount of red coloring. The streaks are more continuous (Fig. 1 B) and the chlorotic spots less conspicuous or absent. Also the discoloration at the base of newly developed leaves is usually lacking. The amount of reddening is often very considerable and a deep purple color appears rather commonly in older leaves. Affected plants are more stunted and in general the disease is more severe. Additional shoots are produced not only in the axils of leaves but also, and mainly, at the base of the stunted plants. This branching is illustrated in Fig. 2 B. The difference in the chlorotic pattern is so striking that those who are acquainted with but one type of corn stunt might hesitate to consider the other type as a closely related disease.

When the survey began it was expected that the Rio Grande type, although not reported previously from Mexico, might be found in regions close to the Texas border, while the Mesa Central type would occur farther south on high elevations. These assumptions were not correct. The Rio Grande type was found not only in northern Mexico near Ciudad Victoria, but also in the south of the country, near Oaxaca. More recently its occurrence in a third region,

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[1] This investigation was supported in part by a grant from the Rockefeller Foundation. The author is indebted to the Agricultural Program of the Foundation in Mexico which provided ample facilities for carrying out this study.

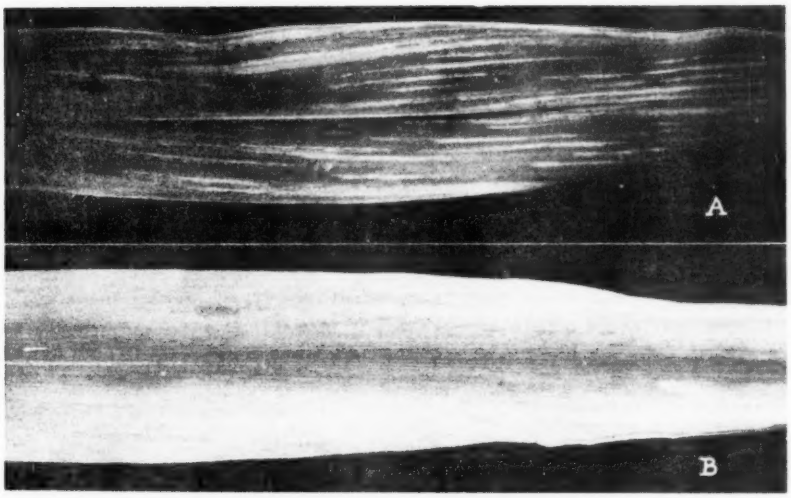


FIGURE 1. Sections of leaves from diseased corn plants of the variety Country Gentleman hybrid, showing striping patterns due to corn stunt. A. -- Rio Grande type. B. -- Mesa Central type. Photographs by J. A. Carlile.

FIGURE 2. Two types of corn stunt. A. -- Rio Grande type with characteristic shortening of upper internodes and secondary shoots in the axils of leaves. Photograph by the Rockefeller Foundation, Mexico. B. -- Mesa Central type, showing severity of stunting and excessive branching. Photograph by J. A. Carlile.

around Vera Cruz, was established by Dr. John S. Niederhauser (personal communication). The Mesa Central type was found, in addition to previously known locations in the Central Plateau, also, for the first time, on the Pacific Coast in the vicinity of Puerto Marquez.

During the survey the two types of corn stunt were not found in the same fields or even in the same geographical region. Whether this distribution was entirely accidental or resulted from strain interference or other factors could not be established. Preliminary field observations indicated that milder strains of both types of corn stunt occur. It is hoped that laboratory studies will provide more information on the possible relationship of the Rio Grande and Mesa Central types. No information is as yet available on the possible occurrence of the Mesa Central type in the United States. Several U. S. commercial varieties of corn were experimentally inoculated using D. maidis as vector. The symptoms of each type were consistently reproduced irrespective of the variety used.

In greenhouse tests it was found that D. maidis was an efficient vector of both types of corn stunt virus. D. elimatus, which has been reported as an efficient vector from Mexico, but which has not been found in California or Texas, has been tested only as a vector of the Mesa Central type.

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# BLAZING GOLD AS A TEST VARIETY FOR THE CHRYSANTHEMUM FLOWER-DISTORTION VIRUS

Philip Brierley[1]

## Summary

The chrysanthemum flower-distortion virus, still uncommon in the United States, is believed to be of European origin. Symptoms and failure to transmit by manual methods suggest that the virus is a member of the yellows group. Occurrence of flower distortion in American chrysanthemum varieties suggests that a vector is present in the United States. Blazing Gold, which shows rosetting of shoot tips 2 months after graft inoculation, is the best test variety known.

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Chrysanthemum flower-distortion virus (1, 2, 3) is still comparatively rare in the United States, having been detected thus far in two garden varieties from a Pennsylvania nursery in 1952 and in four florists' varieties from a Missouri greenhouse in 1954. It is the most virulent of the viruses thus far encountered in chrysanthemum, but its economic importance depends on its natural means of transmission, if any. The usual manual methods of transfer--sap inoculation with extracts of leaves or flowers in water or in phosphate buffer and Yarwood's fresh leaf method -- have failed to produce infection. Among various varieties infected by graft transfer, particularly those useful for detecting stunt or other chrysanthemum viruses, Blazing Gold proved the only variety to express well-defined leaf symptoms of flower distortion within a reasonable time.

Symptoms in Blazing Gold are tight rosetting of vegetative shoots with internodes much shorter than normal ones and upper leaves small, pale and usually deformed (Fig. 1). Such effects are recognizable 2 months after grafting with scions of White Wonder from Pennsylvania or Indianapolis varieties from Missouri. If the Blazing Gold stock is flowered 3 or 4 months after graft inoculation, the flowers are conspicuously smaller than normal and the ray florets are short, narrow, and curled inward or irregularly (Fig. 2). Under greenhouse conditions at Beltsville the virus is lethal to some varieties, causing root and stem rot. Lethal effects develop in Blazing Gold 5 to 7 months after graft inoculation. The source variety White Wonder and the Indianapolis varieties show the same lethal tendencies but can be maintained by frequent propagation from young shoots. The Yellow Spoon source variety shows no lethal effects. Grafts from it induce symptoms in Blazing Gold of the same type as the source varieties mentioned earlier, but more slowly, rosetting Blazing Gold after 3 or 4 months with lethal effects after 7 months. The Yellow Spoon source variety carries the viruses of mosaic and tomato aspermy as well as flower distortion. At present we have no means of determining whether Yellow Spoon carries a milder strain of the flower-distortion virus than other varieties do or whether the effects of the strain in it are weakened by the presence of the other viruses. However, slower reaction indicates that propagators will be wise to flower the Blazing Gold test variety whenever diagnosis from vegetative characters is inconclusive.

Some of the symptoms produced by the flower-distortion virus, together with its failure to transfer by manual methods, suggest that it belongs to the yellows group of viruses. Lethal effects such as noted for flower-distortion virus also follow infection with aster-yellows virus and presumably result from impaired translocation. Plants of the varieties Dynamo and Pandora propagated from plants graft-infected with flower-distortion virus 10 to 11 months ago, now show general yellowing in young leaves and dull-yellow vein-banding in old basal leaves. Such plants of Dynamo and similarly infected plants of Mary MacArthur show proliferation of lateral buds and short shoots with small yellowish leaves. The resemblance in symptom production by flower-distortion and aster-yellows viruses therefore suggests a general group affinity rather than a close relation.

Flower distortion is believed to be a recent introduction from Europe, where it has been known for several years (1). It is unlikely that this disease has long been present but unrecognized in the United States because the variety Blazing Gold failed to detect flower-distortion virus when used as a test stock for stunt virus in the extensive reselection program carried

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FIGURE 1. Blazing Gold chrysanthemums in 6-inch pots. Left, graft-inoculated March 1, 1955; right, uninoculated but pinched when the other was grafted. Photographed June 13, 1955 by M. L. Jaeger.

FIGURE 2. Flowers of Blazing Gold chrysanthemums. Left, from a healthy plant and right from one graft-inoculated with flower distortion virus Oct. 6, 1954. Photographed Feb. 18, 1955, by Otis Greeson.

out by Yoder Bros. in 1946-50. Since that time a great many English chrysanthemums have been imported for use as florists' pot plants or in gardens, and these have been featured in many nursery catalogs. It is notable, however, that the few plants found affected in this country thus far have all been American varieties, not imports. Therefore, the flower-distortion virus, if recently imported as we assume, must have a natural agent of transmission in this country. Flower-distortion-virus is ruinous to affected plants; if it has an efficient vector it can assume major importance, at least in outdoor chrysanthemums.

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# NITROGEN SOURCE OF THE HOST NUTRITION IN RELATION TO INFECTION BY A ROOT-KNOT NEMATODE, MELOIDOGYNE INCOGNITA

Bakir A. Oteifa

In connection with experiments on the nutrition of lima bean plants, Phaseolus lunatus L., in relation to disease development incited by a root-knot nematode, Meloidogyne incognita (Kofoid & White, 1919) Chitwood, 1949, investigation of the effect of nitrogen ammonia and nitrogen nitrate in the host nutrition on the response of the host plant when subjected to nematode infection was suggested. Method of preparing the nematode inoculum and the composition of nutrient solutions were described by the writer in a previous paper[1]. The $NO_3$ solution was the same as the complete solution (NPK). In the $NH_4$ solution $Ca(NO_3)_2$ and $KNO_3$ were replaced by $CaCl_2$ and KCl respectively and an equal number of nitrogen atoms were added in the form of $NH_4Cl$.

Table 1 shows the rate of nematode reproduction and the response of the host plant as influenced by the two nitrogen sources. Data reveal that differences in fresh weights between the uninoculated plants supplied with nitrate ions and those supplied with ammonia ions were not significant. On the other hand, there were significant differences in the case of inoculated plants. The differences between nitrate and ammonia sources of nitrogen were highly significant when plants were inoculated with 200 egg masses. Both number of mature females and number of egg masses produced per gram of root were greater in plants which received nitrate

Table 1. Effect of nitrogen ions on growth of lima beans and rate of reproduction of Meloidogyne incognita.

| Types of nitrogen | Unit of inoculum (egg mass) | Root-gall index[a] | Plant fresh weight (gm.) | No. of females per gm. root | No. of egg masses per gm. root | Rate of reproduction[b] |
|---|---|---|---|---|---|---|
| | 0 | 0.0 | 207.1 | 0 | 0 | 0.0 |
| $NO_3$ | 50 | 2.8 | 160.4 | 201 | 94 | 0.468 |
| | 200 | 4.0 | 104.7 | 468 | 211 | 0.450 |
| | 0 | 0.0 | 200.3 | 0 | 0 | 0.0 |
| $NH_4$ | 50 | 2.0 | 177.8 | 149 | 68 | 0.456 |
| | 200 | 3.0 | 140.4 | 236 | 112 | 0.474 |
| Least significant difference | | | | | | |
| 0.05 | | | 17.9 | 55.7 | 14.8 | 0.119 |
| 0.01 | | | 24.6 | 78.2 | 20.8 | 0.167 |

[a] Root-gall index. This index was based on the relative amount of root galling, the root system being classified as follows: 0 = no evidence of galling; 1 = trace of galling; 2 = moderate galling; 3 = extensive galling; 4 = severe galling.

[b] Rate of reproduction = number of egg masses divided by number of mature females.

nitrogen as compared to those which received ammonia nitrogen. Root-gall index was also found to be higher in the nitrate treatment than in the ammonia treatment. Despite the differences in numbers of females and egg masses produced under the two treatments, rates of nematode reproduction were equal, indicating that development of the parasite within root tissues was independent of the type of nitrogen ions.

In general, ammonia decreased the amount of nematode injury as well as the number of

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females and egg masses produced on infected roots. This decrease was possibly due to the inhibitory effect of the ammonia ions on the hatching of eggs used for inoculum. Once nematodes were able to hatch and infect the host plant they apparently were able to develop normally within the host tissue.

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# SEASONAL FLUCTUATIONS IN THE POPULATION OF MEADOW NEMATODES IN THE ROOTS OF CULTIVATED BRAMBLES IN NORTH CAROLINA

A. C. Goheen and C. F. Williams[1]

## Summary

Carolina and Earliness, two varieties of trailing blackberries, were found to support smaller populations of meadow nematodes, Pratylenchus sp., than other varieties of brambles at Raleigh, North Carolina, on the basis of counts made during a year. The maximum population of meadow nematodes in the roots of brambles was found about June 1, after which it declined rapidly and remained at a lower level through the summer, fall, and winter until plant growth started again in spring.

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Nematode populations in the soil apparently fluctuate with season. In a study of the annual cycle of free-living soil nematodes in a mountain meadow in Austria, Seidenschwarz (4) found the greatest number in August and the fewest from November through January. Different species of nematodes attained maximum populations at different times of year. Similar fluctuations in the population of specific soil nematodes were observed by Micoletzky (2).

Populations of plant-parasitic nematodes in the rhizosphere of plants apparently also fluctuate with season. Graham (1) and Sasser (3) found that the initial population of meadow nematodes in soil before any crop is planted in the spring is largely determined by the previous crop. Graham (1) found that the population of meadow nematodes in tobacco roots built up during the spring and summer, reached a peak in early August, and then decreased sharply. It reached a peak in corn roots in early September. It continued to increase in cotton and crabgrass roots into October. Less is known about the fluctuation of populations of meadow nematodes in the roots of perennial crop plants, which remain in the same location from year to year. This report concerns the fluctuation of meadow nematodes in the roots of 6 cultivated bramble varieties at Raleigh, North Carolina, during a single year.

The varieties used in this study were Carolina, Earliness, Manteo, Brainerd, Cameron, and Lucretia, all trailing or semi-erect blackberries, except Manteo, a black raspberry. All had been established at random in selection blocks in the field for 4 years prior to the first sampling date. It is believed that position had no bearing on the nematode population because the field soil was very uniform.

From May 1954 to May 1955, samples of feeder roots were gathered by the junior author from each of the six varieties about the first of each month except December and February. The roots were taken from approximately the same location on each sampling date. They were freed of soil and forwarded to Beltsville with precautions to prevent drying out in transit.

At Beltsville the meadow nematodes in each root sample were counted by a method adapted from Graham (1). The feeder roots were thoroughly washed to free them of adhering soil particles. Exactly 1 gm of damp roots was then weighed from each sample and placed in the bottom of a standard 90-mm Petri dish. The roots were covered with water (about 35 ml) and held for 4 days or longer. Roots were then removed from the dish and the nematodes that had migrated from them and settled to the bottom of the dish were counted under the microscope at sufficient magnification to be sure that all counted were Pratylenchus. For each sample, the nematodes from 25 random microscope fields were counted and, on the basis of the ratio between the areas of the field and of the dish, the number of nematodes in 1 gm of roots was determined. Single nematodes from some of these collections were mounted and found to be Pratylenchus vulnus.

The meadow nematode count for each variety on each sampling date is given in Table 1. For purposes of comparing the nematode populations on varieties and on sampling dates, the total nematodes counted for each variety and for each sampling date are also given.

On the basis of the total counts, the varieties Carolina and Earliness had significantly fewer nematodes in their roots than Lucretia, Brainerd, and Cameron. Nematodes built up in the roots of Carolina and Earliness during the spring of 1955, but in the same period they were

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Table 1. Meadow nematodes recovered on different sampling dates from 1 gm. of feeder roots of each of 6 cultivated bramble varieties from Raleigh, North Carolina.

| Sampling date | Nematode count | | | | | | Sampling date total |
|---|---|---|---|---|---|---|---|
| | Carolina | Earliness | Manteo | Lucretia | Brainerd | Cameron | |
| 1954 | | | | | | | |
| May | 448 | 2,128 | 2,240 | 4,624 | 5,888 | 3,744 | 19,072 |
| June | 112 | 2,688 | 7,424 | 7,120 | 9,248 | 5,136 | 31,728 |
| July | 176 | 1,152 | 1,776 | 448 | 336 | 0 | 3,888 |
| August | 360 | 168 | 384 | 720 | 648 | 408 | 2,688 |
| September | 0 | 0 | 0 | 48 | 240 | 120 | 408 |
| October | 48 | 24 | 24 | 312 | 432 | 1,968 | 2,808 |
| November | 0 | 24 | 494 | 914 | 469 | 1,531 | 3,432 |
| 1955 | | | | | | | |
| January | 0 | 0 | 18 | 36 | 247 | 148 | 449 |
| March | 75 | 0 | 108 | 914 | 606 | 1,046 | 2,749 |
| April | 357 | 523 | 589 | 1,602 | 797 | 2,216 | 6,084 |
| May | 593 | 1,433 | 1,383 | 4,347 | 2,939 | 7,012 | 17,707 |
| Variety total | 2,169 | 8,140 | 14,440 | 21,085 | 21,850 | 23,329 | |

| L. S. D. | Variety totals | Sampling date totals |
|---|---|---|
| .05 | 12,132 | 8,916 |
| .01 | 16,496 | 11,591 |

more abundant in the roots of Lucretia, Brainerd, and Cameron. This indicates that meadow nematode tolerance might have been one of the characters selected when Carolina and Earliness were first tested and named. The population of meadow nematodes in the roots of Manteo was not significantly less than in the roots of Lucretia, Brainerd, or Cameron.

On the basis of sampling date totals, the maximum population of meadow nematodes in the roots occurred about the first of June. This maximum can probably be correlated with maximum root growth. During the summer the population decreased markedly and stayed at a low level with minor fluctuations during fall and winter. In spring it increased rapidly as the plants started to grow again.

To give a true picture of nematode-host plant relationships, the population of nematodes must be studied throughout the season. As Graham (1) observed in his tobacco root-rot studies, a single population count made on only one sampling date may be very misleading.

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# D-D FUMIGATION OF SOIL FOR THE CONTROL OF PARASITIC NEMATODES IN STRAWBERRIES

A. C. Goheen[1]

## Summary

Preplanting fumigation of a clay loam at Beltsville, Maryland, with D-D at the rate of 30 gallons per acre reduced the population of meadow nematodes in the soil so that it was significantly reduced in the roots of Aroma and Blakemore strawberry plants sampled at the end of the first fruiting season. In the clay loam used in the experiment fumigation did not affect yields the first fruiting season but it improved them significantly the second.

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Parasitic nematodes apparently cause considerable damage to strawberry plants. Allen and Raski (1) reported that fumigation of soil in an old apple orchard with D-D at the rate of 40 gallons per acre or CBP-55 at 30 gallons per acre reduced the meadow nematode population and increased the growth of strawberry plants grown there. Horn and Martin (5) found that fumigation with ethylene dibromide of soils infested with Meloidogyne hapla improved growth and yield of strawberries, and also in one test in soil heavily infested with Tylenchorhynchus claytoni it improved growth. Braun (2, 3) likewise got improved growth and yield when soil was fumigated with ethylene dibromide even though the mother plants were infected with nematodes. This paper is a preliminary report on similar beneficial results from soil fumigation of strawberries in studies conducted from 1953 to 1955 at Beltsville, Maryland.

A clay loam in which strawberry nematodes were known to be present was selected for the fumigation plots. Prior to the experiment strawberry plants heavily infected with meadow nematodes, Pratylenchus pratensis and P. penetrans, and to a less extent with the northern root-knot nematode, Meloidogyne hapla, had grown on this soil. A few lance nematodes, Hoplolaimus sp., were present.

The fumigant used was D-D applied once at the rate of 30 gallons per acre with a hand injector at intervals of 1 foot each way. It was applied on April 24, 1953, after the field had been fertilized and fitted.

Nematode-free and nematode-infected Aroma and Blakemore strawberry mother plants were used. The nematode-free plants were from stocks growing in methyl bromide-treated soil in a screenhouse and the nematode-infected ones were from nematode-infected stocks growing in a nearby field. All plants necessary for the experiment were dug the same day in early April and held at 32° F in polyethylene bags.

Nematode-infected mother plants of each variety were set in plots of fumigated and of non-fumigated soil. Nematode-free plants of each variety were set in plots of fumigated soil. The plots were 7 by 16 feet with 4 mother plants spaced in the center of each so that a bed of plants 12 feet long by approximately 2 feet wide was formed for yield tests. The plots were arranged in randomized blocks and replicated 5 times. The mother plants were set on June 2, or 39 days after fumigation, to allow ample time for the fumigant to escape.

The plants in the plots were rated for growth, yield, and nematode population. Growth was rated at intervals during the first year. Yield data were obtained in 1954 and 1955. Nematode populations of the plant roots were determined several times during the course of the study.

All mother plants survived. In some plots the plants appeared slightly better than in others during the first year, but no consistent growth differences resulted from treatment. Likewise, at the end of the 1954 fruiting season no great growth differences were apparent. At the end of the 1955 fruiting season, however, the plants in the fumigated plots, whether they were from nematode-free or nematode-infected mother plants, appeared much better than the plants in the non-fumigated plots, as shown in Figure 1.

Yield of fruit in the 1954 season roughly correspond to the appearance of the plants in the plots. No significant differences were found. However, during the 1955 season yields showed marked differences as a result of soil fumigation. Blakemore yielded more fruit than Aroma, but the varieties responded similarly to soil fumigation. In fumigated soil, nematode-free plants yielded slightly more than nematode-infected plants and the latter in turn yielded 20 per-

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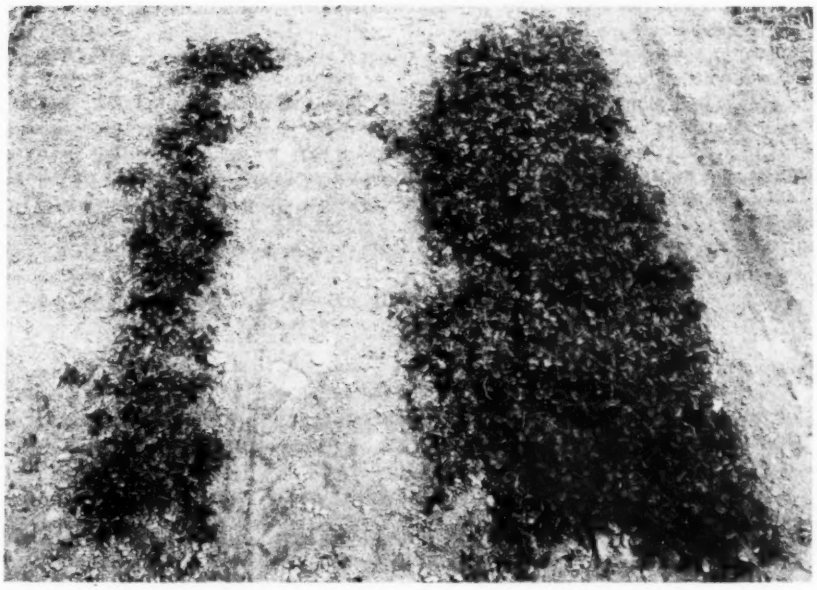

FIGURE 1. Aroma strawberry plots on July 19, 1955, both set with nematode-infected mother plants on June 2, 1953. Left non-fumigated soil; right, soil treated with 30 gallons of D-D per acre prior to setting of mother plants.

Table 1. Meadow nematode population and mean yield of fruit of 2 strawberry varieties in D-D fumigation plots at Beltsville, Maryland, 1953-55.

| Mother plants | Soil treatment (1953) | | Nematodes per gram of roots (June 1954) | Yield per plot (1955) |
|---|---|---|---|---|
| | Fumigant | Rate per acre Gal. | No. | Kg. |
| Nematode-free | D-D | 30 | 350 | 10.94 |
| Nematode-infected | D-D | 30 | 270 | 10.31 |
| Nematode-infected | -- | -- | 1,092 | 8.57 |
| L.S.D. | | | | |
| 5% | | | 690 | 1.66 |
| 1% | | | 942 | 2.26 |

cent more than nematode-infected plants in non-fumigated soil (Table 1). Yield differences between plants in fumigated and non-fumigated soil were highly significant, but those between nematode-free and nematode-infected mother plants set in fumigated soil were not significant. Soil fumigation had no effect on berry size either year.

Nematode populations in the plant roots did not show any consistent differences during the first year, when in general there were very few nematodes. By the end of the 1954 fruiting season meadow nematodes, however, had become established in the plants in all plots. Plant roots in fumigated plots contained significantly fewer nematodes than those in non-fumigated

(Table 1). By the end of the 1955 fruiting season approximately equal popluations of meadow nematodes had built up in the plants in fumigated and non-fumigated plots. Root-knot nematode galls were found on some of the plants and a few lance nematodes were found in the soil of some of the plots at the end of both fruiting years.

This experiment demonstrated the value of soil fumigation with D-D to control parasitic nematodes in strawberry plantings on heavy soil even where nematode-infected mother plants were used. Where nematodes build up rapidly, as in sandy soils like those in which Darrow and Waldo (4) found rapid multiplication of root-knot nematodes on strawberry roots, the value of soil fumigation might be much greater. Under these conditions nematode-free mother plants might also be of considerable value.

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HORTICULTURAL CROPS RESEARCH BRANCH, AGRICULTURAL RESEARCH SERVICE, UNITED STATES DEPARTMENT OF AGRICULTURE

## SOME PARASITIC NEMATODES ASSOCIATED WITH BLUEBERRY ROOTS

A. C. Goheen and A. J. Braun[1]

During the past growing season samples of roots, with the adjacent soil, taken from blueberry bushes showing symptoms of decline were sent to the authors from Massachusetts and North Carolina, and similar samples were collected by them in New Jersey and Maryland. These were examined for ecto- and endo-parasitic nematodes. Species of the following genera were found at least once from the States named: Tetylenchus from Massachusetts, New Jersey, and Maryland; Meloidogyne (root-knot nematode) from North Carolina; Xiphinema (dogger nematode) from Massachusetts and Maryland; Trichodorus (stubby-root nematode) from Maryland and North Carolina; Helicotylenchus (spiral nematode) from Maryland and North Carolina; Hoplolaimus (lance nematode) from Maryland; and Dolichodorus (awl nematode) from North Carolina.

A species of Tetylenchus was the parasite found most frequently. In some samples large numbers of this nematode were present, suggesting possible pathogenicity. Meloidogyne incognita was the only endoparasite found and that was noted in only a single collection from Currie, North Carolina. None of the other nematodes were found in large numbers.

Unpublished records of the Nematology Section of the Horticultural Crops Research Branch show that Helicotylenchus has also been identified in blueberry samples from New Jersey.

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# SILICONES AS LUBRICANTS FOR PEA SEED PROTECTANTS[1]

J. J. Natti and W. T. Schroeder

## Summary

Delsan A-D, Ortho Seed Guard, and Orthocide 75 decreased the rate of delivery of pea seed through a grain drill 13 to 15 percent less than that of untreated seed. Arasan dust decreased it 4 percent. Spergon did not influence the rate of delivery.

Each of the silicone emulsions LE-45, LE-46, and X-521 when superimposed on Orthocide 75 dust treatment of pea seed eliminated most of the retarding influence of this seed protectant on the delivery of seed from the grain drill. Similarly, these silicone emulsions used as slurry media with Delsan A-D and Ortho Seed Guard eliminated most of the retarding influence of these materials on the flow of seed through the grain drill.

In tests in which pea seed was germinated on moistened filter paper in enclosed Petri dishes, each of the silicone emulsions alone, or in combination with seed protectants, reduced the germination of the seed and retarded the development of plumules and roots. In soil plantings in the greenhouse and field, the silicone emulsions had no apparent effect on germination and subsequent development of the seedlings.

The silicone emulsions did not alter the pesticidal value of either the fungicide or the insecticide contained in Delsan A-D or Ortho Seed Guard.

## INTRODUCTION

The treatment of seed for protection against decay organisms in the soil involves coating the seed with a protecting fungicide. This coating imparts to the surface of the seed the physical properties of the material used as a protectant. Thus, some materials may possess lubricative properties and increase the rate of flow through a planter; whereas, others may increase the interfacial friction between treated seed and so retard the rate of flow. Those that are frictionable, even though they are effective protectants, may result in stands lower than desirable because of a retarded rate of delivery of the seed from the planter, or because of a sporadic delivery from bridging of the seed in the planter. Mechanical injury to the seed may also occur and contribute to low stands. Some of the most effective seed protectants in current use are handicapped by frictionable properties. A lubricant to overcome this undesirable feature would enchance the value of these materials as protectants, especially for pea seed. Graphite has been used successfully as a seed lubricant when combined with some protectants, but it has not been accepted by growers because of its dark color and its tenacity to skin and clothing.

In 1955, each of three silicone emulsions tested as lubricants for captan or thiram on pea seed overcame the frictionable properties of these materials. Laboratory germination tests of pea seeds so treated indicated some injury, but no apparent adverse effects were noted when the treated seed was planted in greenhouse and field soil. In view of these initial findings, further tests on silicones as lubricants were deemed advisable.

## MATERIALS AND METHODS

Silicone emulsions LE-45, LE-46, and X-521, supplied by Linde Air Products Company[2], were tested as seed lubricants. Pea seeds (Wilt Resistant Surprise) were treated with the silicone emulsions alone, with silicone emulsions superimposed upon a previous treatment with Orthocide 75, and with slurry treatments of Delsan A-D and Ortho Seed Guard in which the silicone emulsions were used in place of water in preparation of the slurry. Other lots of the same seed were treated with seed protectant alone, or remained untreated. Thorough coverage of the seed was obtained by rotating the seed and the treatment materials for 3 minutes in a glass container mounted on a revolving wheel.

The influence of seed treatment on the rate of delivery of seed from the grain drill was determined in the laboratory. The equipment consisted of a short section of an Ontario grain

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[1] Approved by the Director for publication as Journal Paper No. 1020. New York Agricultural Experiment Station, Geneva, New York.

[2] Division of Union Carbide and Carbon Corporation, Buffalo, New York.

Table 1. Influence of silicone coatings on delivery of peas from a grain drill in laboratory tests.

| Treatments[a] | | Seed delivery | |
|---|---|---|---|
| Pesticide | Silicone | Seed delivered per minute[b] (gm) | Difference from amount of untreated seed delivered[c] (per cent) |
| — | — | 270 | — |
| — | LE-45 | 285 | + 5.5 |
| — | LE-46 | 286 | + 5.9 |
| — | X-521 | 263 | - 2.2 |
| Orthocide 75 | — | 230 | -14.8 |
| Orthocide 75 | LE-45[d] | 270 | 0.0 |
| Orthocide 75 | LE-46[d] | 260 | - 3.7 |
| Orthocide 75 | X-521[d] | 267 | - 1.1 |
| Delsan A-D | — | 232 | -14.1 |
| Delsan A-D | LE-45[e] | 265 | - 1.9 |
| Delsan A-D | LE-46[e] | 258 | - 4.4 |
| Delsan A-D | X-521[e] | 272 | + 0.7 |
| Ortho Seed Guard | — | 235 | -13.0 |
| Ortho Seed Guard | LE-45[e] | 257 | - 4.8 |
| Ortho Seed Guard | LE-46[e] | 248 | - 8.1 |
| Ortho Seed Guard | X-521[e] | 270 | 0.0 |
| Arasan | — | 260 | - 3.7 |
| Spergon | — | 269 | - 0.4 |
| Least difference required for significance | (19:1) | 5 | |
| | (99:1) | 7 | |

[a]LE-45, LE-46, and X-521 applied at rate of 1/2 pt./bu.; Orthocide 75, 1.3 oz.; Delsan A-D, 1.7 oz.; Ortho Seed Guard, 1.95 oz.; Arasan (50%), 2.1 oz.; and Spergon, 2.0 oz. per bushel.

[b]Average weight of 8 determinations.

[c]+ indicates amount of seed delivered exceeded that from untreated seed; - indicates amount of seed delivered was less than that from untreated seed.

[d]Silicone treatment superimposed on treatment with Orthocide 75.

[e]Silicone emulsion used in place of water in preparation of slurry.

drill mounted to a table and driven by an electric motor. The drill was adjusted to a speed equivalent to 15 r.p.m. of a 5-inch pulley attached to the shaft of the grain drill. The rate of delivery of treated seed from the drill was determined by weighing the amount of seed delivered from a single drill tube in one minute.

The influence of silicone treatments on germination of seed was tested in the laboratory. Fifty seeds from each treatment lot were placed in Petri dishes containing moistened filter paper. The Petri dishes were covered and the seeds were allowed to germinate at room temperature. Water was added whenever the filter paper began to dry. The germinated seeds were counted 10 days after seeding.

In the greenhouse, seed was planted on May 16 in soil heavily contaminated with seed-decay and damping-off organisms, especially Rhizoctonia spp. The plantings consisted of four replications of 50 seeds each for each treatment. The total number of plants from all treatments was counted on May 24.

In the field, seed was planted in light sandy soil on April 21. The planting consisted of six replications of 100 seeds each for each treatment. The total stand and the number of weak plants (injured by maggot, wireworm, or treatment) were counted on May 13.

## EXPERIMENTAL RESULTS

### Influence of Seed Treatments with Silicone on Delivery of Pea Seed from a Grain Drill

The influence of seed treatment on the delivery of pea seed from the grain drill is indicated by the percentage differences between the amount of seed delivered per minute from the treated seed samples and the untreated control (Table 1).

On that basis, treatment of seed with silicone emulsions LE 45 or LE-46 resulted in an increase of about 6 percent, while emulsion X-521 resulted in a decrease of about 2 percent in the amount of seed delivered. The latter material is waxy and the treated seeds tended to form aggregates in which the individual seeds were held together by the wax.

Orthocide 75 applied as a dust reduced the amount of seed delivered by about 15 percent and Arasan dust by 4 percent, while Spergon had no appreciable influence. The superimposition of silicone emulsions LE-45 or X-521 on seed previously treated with Orthocide 75 overcame the retarding influence of that material. Emulsion LE-46 was not so effective as the other silicones.

Delsan A-D slurry prepared with water resulted in a 14 percent decrease in the amount of seed delivered. Silicone emulsions substituted for water in preparation of the Delsan A-D slurry eliminated most of this decrease in rate of flow. Silicone emulsion X-521 increased the amount of seed delivered by about 1 percent over that of untreated seed, while emulsions LE-45 and LE-46 decreased it by 2 and 4 percent, respectively.

Ortho Seed Guard slurry prepared with water resulted in a 13 percent decrease in the amount of seed delivered. Silicone emulsion X-521 substituted for water in the preparation of the slurry resulted in a rate of delivery identical to that of the untreated seed. The amount of seed delivered from treatments in which silicone emulsions LE-45 and LE-46 were similarly used averaged 5 and 8 percent less, respectively.

### Influence of Seed Treatments with Silicone on Germination of Pea Seed in Laboratory Tests and Emergence from Silicone-treated Seed in Greenhouse and Field Tests

Laboratory Tests. In tests in which pea seed was germinated on moistened filter paper in Petri dishes, treatments with silicone alone resulted in a reduction in germination. Seed treatments with silicone emulsion X-521 caused the greatest reduction. In treatments in which silicone emulsion was superimposed on seed treatment with Orthocide 75, or in treatments in which silicone emulsion was substituted for water in preparation of slurry mixtures, the number of germinated seeds, in most instances, was less than that from treatments with pesticides alone, or from the untreated seed (Table 2).

Silicone emulsions, whether applied alone or in combination with pesticides, retarded plumule and root development of pea seed germinated in Petri dishes. Ten days after seeding the Petri dishes, the length of plumules of seed not treated with silicones averaged 3 cm. Plumule growth from seed treated with silicones averaged less than 1 cm in length. The length of the roots developing from seed not treated with silicone averaged 4.5 cm, whereas that from seed treated with silicones averaged 1.5 cm. Most of the seed treated with silicone emulsions alone underwent bacterial decomposition about 12 days after seeding in the Petri dishes.

Greenhouse Test. The total emergence from untreated seed and from seed treated with silicone emulsions alone was less than that from seed which had been treated with a pesticide. Silicones alone did not adversely affect the emergence and subsequent development of the pea seedlings. Emergence from treatments with Orthocide 75 dust was greater than that from treatments in which silicone emulsion was superimposed on dust treatment with Orthocide 75. Emergences from treatments in which silicone emulsions were used as slurry media for Delsan A-D and Ortho Seed Guard were comparable to those from slurry treatments of these materials prepared in the recommended manner (Table 2).

Field Test. Seed decay and injury from seed-corn maggot were not severe, but were sufficient to indicate that the silicone emulsions had no adverse effects on the pesticidal properties of the treatments.

Total emergence from seed treated with silicone emulsion alone was comparable to that from untreated seed. Emergence from seed treated with a fungicide was greater than that from

Table 2. Germination of pea seed treated with and without silicones in Petri dishes, in greenhouse soil, and in field soils.

| Treatments | | Germination | Total emergence | | Weak plants |
|---|---|---|---|---|---|
| Pesticide | Silicone | Lab. (per cent) | Greenhouse (per cent) | Field (per cent) | Field (per cent) |
| — | — | 98 | 21 | 67 | 4.0 |
| — | LE-45 | 72 | 20 | 70 | 2.7 |
| — | LE-46 | 62 | 39 | 71 | 4.5 |
| — | X-521 | 20 | 35 | 69 | 4.5 |
| Orthocide 75 | — | 94 | 82 | 76 | 3.0 |
| Orthocide 75 | LE-45 | 72 | 62 | 73 | 3.3 |
| Orthocide 75 | LE-46 | 94 | 78 | 79 | 3.3 |
| Orthocide 75 | X-521 | 74 | 73 | 79 | 2.7 |
| Delsan A-D | — | 96 | 50 | 79 | 0.8 |
| Delsan A-D | LE-45 | 84 | 48 | 80 | 0.5 |
| Delsan A-D | LE-46 | 82 | 58 | 80 | 0.8 |
| Delsan A-D | X-521 | 72 | 55 | 79 | 1.0 |
| Ortho Seed Guard | — | 94 | 65 | 78 | 1.2 |
| Ortho Seed Guard | LE-45 | 76 | 72 | 84 | 0.5 |
| Ortho Seed Guard | LE-46 | 72 | 66 | 83 | 1.0 |
| Ortho Seed Guard | X-521 | 52 | 61 | 83 | 0.5 |
| Arasan | — | 100 | 47 | 78 | 3.0 |
| Spergon | — | 96 | 74 | 77 | 3.7 |
| Least difference required for significance | | (19:1) | 6 | 5 | 1.2 |
| | | (99:1) | 8 | 7 | 1.6 |

seed not treated with a fungicide with the single exception of the treatment with silicone emulsion LE-45 superimposed on a dust treatment with Orthocide 75. Emergences from slurry treatments with Delsan A-D and Ortho Seed Guard in which silicone emulsions were used as slurry media were comparable to those from treatments with pesticides alone (Table 2).

The number of weak plants from seed treated with Delsan A-D or with Ortho Seed Guard, treatments which contain both a fungicide and an insecticide, was significantly less than that from the treatments which contained no insecticide. The weak plants, in most instances, showed evidence of seed-corn maggot and wireworm injury. The substitution of silicone emulsion for water in preparation of slurry mixtures of these fungicide-insecticide combination seed protectants, therefore, had no adverse effect on the pesticidal value of the fungicide or the insecticide under the conditions of this test (Table 2).

## DISCUSSION

The results of these tests on the possibilities of incorporating silicone with a seed protectant to overcome the frictionable properties of the seed treatment material indicate that silicones warrant further consideration as lubricants for seed. Each of the silicone emulsions was effective in minimizing the retardation in rate of delivery of seed from a grain drill resulting from treatment of the seed with Delsan A-D, Orthocide 75, and Ortho Seed Guard. No attempt was made to determine the minimum concentration of silicone necessary to provide sufficient lubrication for the various pesticides.

The adverse effect of treatment of pea seed with silicone emulsion on the germination of the seed and on the subsequent development of plumule and roots in laboratory tests in which the seed was planted in Petri dishes suggests that the silicones are injurious to the seed. However, in greenhouse and field tests in which the treated seed was planted in soil, no injurious effects from seed treatment with the silicones were observed. Because silicones are considered to be inert, it is more likely that the dispersing medium of the emulsion rather than the silicone was responsible for the adverse effects observed. The reduction in germination from the same treatments in soil tests lends support to the interpretation that the liquid phase of the emulsion contained the toxic principle. In the Petri dish tests, the seed remained in contact with the original concentration of the dispersing medium of the silicone emulsion for the duration of the tests. In the soil plantings, on the other hand, the concentration of the liquid phase of the emul-

sion was undoubtedly diluted by water in the soil and some of the toxic principle probably was adsorbed by soil organic matter and colloids.

Coating of the seeds with the silicone emulsions did not appear to interfere with the imbibition of water by the seeds. Seeds treated with silicones became swelled at the same rate as did the untreated seeds when placed in contact with moistened filter paper.

In further investigations, the effectiveness of silicones as seed lubricants under field conditions in which machine planters are used should be determined. Also, other silicone preparations should be tested as seed lubricants, particularly dust or liquid formulations free from toxic carriers.

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# PENTACHLORONITROBENZENE FOR CONTROL OF CLUBROOT OF CRUCIFERS[1]

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## Abstract

Pentachloronitrobenzene (PCNB) gave effective control of clubroot of cauliflower and broccoli when mixed with the soil at the rate of 80 pounds of active ingredient per acre before planting or when used in transplant water at 2, 4, or 8 pounds per 100 gallons. Plants receiving PCNB developed excellent fibrous root systems with only a few small clubs appearing on their extremities; these plants produced yields normal for the season. At the rate of 2 pounds of PCNB per 100 gallons of transplanting water, clubroot control could be provided for about 15 dollars per acre (12, 000 plants) where one-half pint of the fungicidal suspension is used around each plant.

Clubroot of crucifers is difficult to control once the pathogen, Plasmodiophora brassicae Wor., becomes established in the soil. Control measures commonly recommended include addition of lime to create an akaline soil, long rotations with non-cruciferous crops, and the addition of fungicides to the transplant water.

Since in West Virginia most soils are naturally acid and the topography sets a sharp limitation on the land area suitable for row-crop culture, application of the first two control measures is often difficult and impractical. Here, the application of fungicides to the soil before planting or their addition to the transplanting water offers the most promising method of control.

Of the various chemicals previously tried for clubroot control, mercuric chloride, applied in the transplant water, has proved most effective (4). Use of this material has been confined to small plantings possibly because of its toxicity and corrosiveness. Recently Campbell (1) reported satisfactory control of cauliflower clubroot by mixing pentachloronitrobenzene (PCNB) with the soil before transplanting, whereas Snyder et al. (3) reported control of clubroot on brussels sprouts with PCNB applied in the transplant water. Previously, Smieton (2) reported some success from the use of PCNB mixed with the soil in flats; however adequate control was not obtained when PCNB was used in the field.

It was desirable to determine whether pentachloronitrobenzene would control clubroot in West Virginia areas where cauliflower and broccoli are grown commercially when the fungicide was applied to the soil before planting or when it was added to the transplanting water. In 1955 an experiment designed to test the effectiveness of this compound and an unnamed experimental fungicide was set up on clubroot-infested soil in the Canaan Valley near Davis, West Virginia.

## Materials and Methods

Pentachloronitrobenzene was supplied by Olin Mathieson Chemical Corporation, Baltimore, as a 75% wettable powder; the experimental compound CC-974 was supplied by Carbide and Carbon Chemicals Company, New York, as a 90% wettable powder. PCNB was applied to the soil in different concentrations by two methods: 1) uniformly mixed in the top 4-inch layer by a rotary tiller; and 2) in the transplanting water. CC-974 was used in one treatment only and was uniformly worked into the top 4-inch layer of soil at the rate of 40 pounds of active ingredient per acre. In the pre-planting soil treatments PCNB was used at the rate of 20, 40, and 80 pounds active ingredient per acre. In the transplant water treatments it was used at 2, 4, and 8 pounds of active ingredient per 100 gallons. The transplant water was applied at the rate of 1/2 pint per plant; at the planting distance of 1 by 3 feet, the equivalent of 900 gallons per acre was used.

For cabbage root maggot control, 5% chlordane dust was applied around each plant after setting except in treatments number 7, 10, and 11. In treatment 7, 50% wettable-powder chlordane (6 pounds per 100 gallons) was mixed with PCNB in the transplant water to determine if the two materials were compatible; in plot 10, PCNB was applied alone in the transplant water; plot 11 received neither the fungicide nor the insecticide.

The eleven treatments were randomized and replicated 4 times. Each treatment consisted

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FIGURE 1. Control of broccoli clubroot by PCNB; from left to right, row 11 received no treatment, row 10 received PCNB only in the transplant water at 4 lbs per 100 gal., row 9 received chlordane dust only.

Table 1. Clubroot index readings on cauliflower and broccoli and yield of broccoli from treatment with varying concentrations of PCNB applied by two different methods.

| Treatment | Fungicide and concentration[a] | Insecticide[b] | Clubroot index | | Broccoli yield pounds per acre | |
|---|---|---|---|---|---|---|
| | | | Cauliflower | Broccoli | Terminal heads | Total |
| 1. | PCNB 20 lbs/acre | Chlordane dust | 73 | 80 | 3017 | 3916 |
| 2. | " 40 lbs/acre | " " | 57 | 55 | 2005 | 4174 |
| 3. | " 80 lbs/acre | " " | 30 | 27 | 3102 | 5187 |
| 4. | " 2 lbs/100 gal. | " " | 29 | 37 | 3525 | 5046 |
| 5. | " 4 lbs/100 gal. | " " | 18 | 35 | 3049 | 4820 |
| 6. | " 8 lbs/100 gal. | " " | 21 | 32 | 2360 | 4138 |
| 7. | " 4 lbs/100 gal. | Chlordane W.P. | 24 | 44 | 3085 | 4468 |
| 8. | CC-974 40 lbs/acre | Chlordane dust | 80 | 76 | 2433 | 3304 |
| 9. | No fungicide | " " | 85 | 88 | 936 | 1662 |
| 10. | PCNB 4 lbs/100 gal. | No insecticide | 25 | 33 | 3811 | 5445 |
| 11. | No treatment --- | --- | 93 | 92 | 738 | 1296 |
| LSD 19:1 | | | 13.9 | 13.1 | -- | 2130 |
| 99:1 | | | 18.7 | 17.7 | -- | 2868 |

[a] In treatments 1, 2, 3, and 8 the fungicide was spread evenly over the soil and worked into the top 4 inches with a rotary tiller; in treatments 4, 5, 6, 7, and 10, the fungicide was applied in the transplant water at the concentrations listed.

[b] Where noted, 5% chlordane dust was applied around each plant immediately after setting; the 50% wettable powder chlordane was mixed in the transplant water with PCNB.

of a row 20 feet long. The rows were spaced 3 feet apart. For the soil-treatment plots, the wettable-powder fungicides were suspended in 5 gallons of water and spread uniformly over the area of 60 square feet before rotary tilling. The plants were set in the center of the treated strip.

Ten plants each of the Imperial Snowball cauliflower and Green Mountain broccoli varieties were set 1 foot apart. At the time of setting, transplant water (the fungicidal suspension or water only) was poured around each plant as it was placed in the soil. The broccoli plants were grown in flats in the greenhouse whereas the cauliflower plants were obtained from a commercial grower. The cauliflower plants "buttoned" (headed prematurely), as did those in commercial fields in the area, so that yield data could not be obtained. The broccoli plants produced normal heads, however, which were cut and weighed as they matured. The yields were converted to pounds per acre.

After harvest the plants were dug and their roots were examined and rated as to severity of clubroot. The following index was used in the clubroot ratings: 0 = no clubs formed; 25 = one to a few small clubs on root extremities only, good fibrous root development; 50 = numerous small clubs on root extremities only, good fibrous root development; 75 = numerous clubs or moderate clubbing at center of root system, poor fibrous root development; 100 = numerous clubs or severe clubbing at center of root system with little or no fibrous root development, or roots completely destroyed by clubroot disintegration.

To determine the disease-index reading for each treatment-replicate, the number of plants in each class was multiplied by the respective rating number; the totals were added; and the sum was divided by the total number of plants in the replicate. The disease-index readings and yield data were analysed by analysis of variance.

The Canaan Valley is about 3,000 feet above sea level, where climatic conditions are normally favorable for cauliflower and broccoli production. The 1955 season was warmer and dryer than normal; this partially accounts for the premature "buttoning" of cauliflower and lowered broccoli yields.

## Experimental Results

The data in Table 1 show the cauliflower and broccoli clubroot index readings and broccoli yields when PCNB was used for clubroot control. All concentrations of PCNB, whether applied to the soil or in the transplant water, gave some control of the disease. The control was not adequate, however, where the soil was treated at the rates of 20 and 40 pounds per acre. Best control was obtained when PCNB was mixed with the soil at 80 pounds per acre or when it was used in the transplant water. Concentrations of 2, 4, and 8 pounds PCNB per 100 gallons of transplant water were apparently equally effective in control; Figure 1 shows the control obtained with 4 pounds PCNB per 100 gallons. The high concentration of chlordane wettable powder did not reduce the effectiveness of PCNB in control of clubroot when both were mixed together in the transplant water. The experimental compound CC-974 at the concentration of 40 pounds per acre gave poor control.

Significant increases in yields of broccoli were obtained by the use of PCNB. Best yields were obtained from soil treatment at 80 pounds per acre and from transplant water treatment of 2 and 4 pounds per 100 gallons; the yields from these treatments were equal to those from clubroot-free commercial fields nearby. No evidence of plant injury was observed from any of the concentrations used. The yields obtained with the CC-974 treatment were higher than those from the controls but they were lower than yields taken from the rows receiving PCNB treatments. Taste tests revealed no off-flavor associated with the use of PCNB.

## DISCUSSION AND CONCLUSIONS

The results obtained with PCNB for control of clubroot on cauliflower and broccoli are encouraging. Where no fungicide was used the plants were usually severely clubbed at the center of the root system, which showed little or no fibrous root development. When PCNB was used at 80 pounds per acre as a soil treatment or as 2, 4, or 8 pounds per 100 gallons in a transplant-water treatment, the plants had a good to excellent fibrous root system with only a few small clubs near the ends of the roots. As illustrated by the data, plants with but few clubbed roots produced yields normal for the season.

It is not known why the control obtained in this work was superior to that reported by Smieton (2) with the same material. It was difficult to determine the exact concentrations she used but they seem to have been lower than those tested here. As pointed out by the experimental data,

concentrations lower than 80 pounds per acre failed to give good clubroot control when spread evenly over the entire row area; however, lower concentrations gave excellent control when concentrated around the plant in the transplanting water.

Although mercuric chloride was not compared with PCNB in this study, it appears that control by PCNB is equal to or better than that reported with mercuric chloride (3). Apparently the disease-index classes used in these experiments differed from those used by Walker et al. (3). Plants from their mercuric chloride-treated plots were given index readings of about 20; the plant from such a treatment shown in their illustration would have been given an index reading of 50 in the present study. Since the severity of clubroot varies from year to year and from locality to locality, different disease-index class descriptions may be required to show differences in disease development.

At the present price, PCNB used at 2 pounds of active ingredient per 100 gallons of transplant water would cost about 15 dollars per acre (12,000 plants) when the transplant water is used at the rate of 1/2 pint per plant. The cost would vary with distance between plants and the gallonage used, but should not be prohibitive to cauliflower and broccoli growers.

In West Virginia, pentachloronitrobenzene will be recommended for crucifer clubroot control if and when this material is cleared by the Food and Drug Administration of the United States Department of Health, Education and Welfare.

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# FIELD CONTROL OF SWEETPOTATO STEM ROT IN ALABAMA[1]

Urban L. Diener

## Summary

The effectiveness of several organic fungicides applied as sprout treatment and of resistant varieties in reducing sweetpotato losses from stem rot, caused by Fusarium oxysporum f. batatas, was investigated. Plants were grown in naturally infested soils. Chloranil, captan, dichlone, and Semesan Bel significantly reduced disease incidence in some years in Alabama. Yield increases did not appear to be related to reductions in stem rot. Sweetpotato yields and disease incidence varied with environmental conditions. Goldrush and Allgold varieties showed marked resistance to stem rot in 1954 and appeared to be well adapted to the growing conditions of certain areas of Alabama.

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Stem rot, caused by Fusarium oxysporum f. batatas (Wr.) Hansen & Snyder, is the most important field disease of sweetpotatoes in Alabama. In the last 5 years, the certified acreage of the Porto Rico variety has declined steadily with the increasing prevalence of the disease.

Harter and Field (3) showed that a low percentage of sprouts from diseased sweetpotato roots became infected by way of the vascular connections. McClure (10) demonstrated the importance of vascular wounds in stem rot infection and concluded that this was the principal mode of sprout infection in the field. Poole (11, 12) found that stem rot infection from field soil was reduced by preplanting immersion of the root and stem end of sprouts in fungicides, especially Bordeaux paste (2-2-5). Other workers (1, 2, 4, 5, 6, 8, 9) have reported similar results with various fungicides in the last 25 years. Porter and Parris (13) in 1943 found sprout treatments ineffective. In the same year, Manns (7) attributed his failure to get increases in yield to drouth during the growing season.

## Materials and Methods

Field experiments were conducted at horticultural substations near Clanton and Cullman, Alabama. Plots consisted of 50 plants in one row, replicated 4 to 6 times. Sprouts were set by hand or by mechanical plant-setter, 12 to 16 inches apart in 36- or 42-inch rows. The roots and basal parts of the stem of sprouts were immersed for 10 to 15 seconds in fungicidal solutions prior to planting in a stem rot-infested soil. The concentrations of the chemicals used for dip treatments were: Chloranil (48%) and dichlone (50%), 2 oz./gal.; captan (75%), 1.5 oz./gal.; Semesan Bel, 1.6 oz./gal.; PCNB (pentachloronitrobenzene) 75%, 1 oz./gal.; and nabam, 75 ml./gal. The Porto Rico variety was used for all slip treatments. Check plots were set with sprouts dipped only in water.

Stand counts of healthy and stem rot diseased plants were made periodically as long as the individual plants could be distinguished. At harvest time, the stems were split at the soil line. Infection was ascertained by the presence of the vascular discoloration typical of fusarial wilt diseases. Isolations were made from random samples of stems in the laboratory for the presence of the causal organism. Yields were recorded in pounds per plot for marketable weight (Nos. 1 and 2) and total weight of roots.

## Results

Disease incidence was low in experimental plots in 1952 and disease data were not recorded. However, sprouts treated with nabam showed significant increases in root yield at both Clanton and Cullman (Table 3). Semesan Bel also gave a significant increase at Clanton.

In 1953 and 1954, sweetpotato land which had severe stem rot the previous year was used for plot work. The effectiveness of fungicidal sprout treatments in reducing stem rot in 1953 is given in Table 1. The stem rot organism infected 15 and 46 percent of the untreated sprouts at Clanton and Cullman, respectively. Dichlone, chloranil, and captan at Clanton, and all treatments at Cullman were significantly better than the check. In 1954, 76 and 42 percent of

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Table 1. Control of sweetpotato stem rot by sprout treatments in Alabama in 1953.

| Treatments | Percent of plants with stem rot | |
|---|---|---|
| | Clanton[a] | Cullman[b] |
| Captan | 2 | 32 |
| Dichlone | 1 | 24 |
| Check | 15 | 46 |
| Nabam | 8 | 25 |
| Semesan Bel | 4 | 23 |
| Chloranil | 1 | 24 |
| L.S.D. (.05) | 14 | 14 |
| L.S.D. (.01) | - | 20 |

[a] Mean of four replications.
[b] Mean of five replications.

Table 2. Control of sweetpotato stem rot by sprout treatments and resistant varieties in Alabama in 1954.

| Treatments | Percent of plants with stem rot | |
|---|---|---|
| | Clanton[a] | Cullman[b] |
| Allgold | 16 | 7 |
| Early Port | 53 | - |
| Georgia Bunch | 40 | - |
| Goldrush | 4 | 4 |
| Heart-o-gold | 93 | - |
| Porto Rico (H-2 strain) | 76 | - |
| Porto Rico (Check) | 76 | 42 |
| Porto Rico - Chloranil Dip | 64 | 32 |
| Porto Rico - PCNB Dip | 82 | 42 |
| Porto Rico - Captan Dip | 50 | 30 |
| L.S.D. (.05) | 13 | 13 |
| L.S.D. (.01) | 17 | 18 |

[a] Mean of six replications.

Table 3. Total yield of Porto Rico Sweetpotato roots grown from chemically-treated sprouts at two locations in Alabama, 1952-54.

| Treatments | Mean yields in pounds per plot | | | | | |
|---|---|---|---|---|---|---|
| | Clanton | | | Cullman | | |
| | 1952 | 1953 | 1954 | 1952 | 1953 | 1954 |
| Nabam | 28 | 31 | - | 79 | 35 | - |
| Chloranil | - | 39 | 6 | 59 | 37 | 32 |
| Dichlone | 25 | 37 | - | 71 | 32 | - |
| Semesan Bel | 33 | 39 | - | 73 | 34 | - |
| Captan 75 | - | 37 | 8 | - | 30 | 29 |
| Check | 20 | 30 | 6 | 53 | 36 | 25 |
| L.S.D. (.05) | 6 | 14 | 4 | 24 | 8 | 10 |
| Replications | 4 | 4 | 6 | 4 | 5 | 6 |

the untreated sprouts were infected with stem rot. Only captan was significantly better than the check at Clanton and showed promise at Cullman (Table 2). The marked resistance of the Goldrush and Allgold varieties to field infection by stem rot is also given in Table 2. At Clanton the Early Port and Georgia Bunch varieties were more resistant than the Porto Rico variety.

Table 3 gives the total yield data for the 3-year period for all chemicals used more than 1 year. In 1954, the Allgold variety produced signficantly more roots at Clanton and Cullman (16 and 12 pounds, respectively) than did Porto Rico. Goldrush, Early Port, and Georgia Bunch produced significantly more roots at Clanton.

Phytotoxic effects were noted with the use of some fungicides in supplementary experiments at three locations in 1953. Semesan Bel and nabam signficantly reduced stands and yields of vine cuttings and sprouts planted 4 to 8 weeks after the other experiments. The toxicity of these chemicals was not evident in early plantings. In 1954, PCNB treated sprouts showed toxic effects by reducing stands, although the yields were not reduced signficantly.

## Discussion

As noted in the introduction, the effectiveness of fungicides in control of stem rot appears to vary with environmental conditions. Rainfall during the growing season was below average in 1952, but there were no extended periods of drouth. In 1953 and 1954, however, drouth periods of 30 to 40 days occurred in May and early June and in August and September at Clanton. At Cullman there was a 30-day drouth in May and June of 1953 with only moderate rain the remainder of the year. In 1954 there were only 2.9 inches of rain from June 20 to September 20 at Cullman. Yield differences did not occur during the drouth years, probably because water rather than the number of plants was the limiting factor in growth. Plots with a half stand of plants yielded as many pounds of roots as did full stands. The roots, though fewer, were much larger. Although disease incidence was high in the check plots, sprout treatments were not effective for stem rot control in 1954.

Stem rot was not prevalent in the experimental plots at Auburn in 1952. Experiments were conducted on stem-rot-infested land in southeastern Alabama near Ashford in 1953 and 1954. Since stem rot was not a factor in these experiments, the data were not included.

The stem rot resistance of the Goldrush and Allgold varieties in Alabama had been noted in variety tests prior to the field studies of 1954, but no actual disease data were taken or published The Goldrush variety, besides showing stem rot resistance, appeared to be unusually well adapted to the light sandy soils and growing conditions of southern Alabama. Allgold, however, did not shape well in southern Alabama and appeared to be better adapted to the soil types and growing conditions of central and northern Alabama.

The toxicity of some treatments, as evidenced by reduced stands and stunted sprouts, was probably related to low moisture and high temperatures at planting time. This interpretation

was supported by the results with vine cuttings and sprouts planted in 1 to 2 months after the other experiments.

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# LATE SEASON TWIG-INFECTION, A SERIOUS LIMITATION TO THE EFFECTIVENESS OF ANTIBIOTIC SPRAYS FOR FIREBLIGHT CONTROL

R. N. Goodman[1]

Since 1952 the control of fireblight, Erwinia amylovora, with antibiotic sprays and dusts, has been reported by workers from practically every region in which this bacterial disease manifests itself. The similarity of the data obtained and unanimity of opinion, stressing the effectiveness of streptomycin in reducing the intensity of fireblight, has resulted in the extensive usage of this antibiotic in commercial apple and pear orchards.

As is often the case, however, with new agricultural procedures, widespread usage frequently occurs before the vagaries of the new technique are fully comprehended. Further, the constancy with which E. amylovora remains inconsistent is well known to all who have studied this organism.

During the past growing season we became cognizant of a serious limitation to the effectiveness of antibiotic sprays in controlling fireblight on Jonathan apple trees. Actually, this limitation, the development of blight infections on vegetative growth 2 to 5 weeks after full bloom, had been observed during the past 3 years; however, its implications were not fully recognized. These late twig infections had previously been presumed to be due to contamination from unsprayed check trees, from unsprayed trees near the experimental plots, and from occasional infected blossom clusters that were not protected by the antibiotic sprays.

## Experimental

Plots consisting of 400 trees were set out in each of two orchards that had perhaps the highest incidence of fireblight noted in Missouri during the 1954 season.

Initially, the primary aims were to ascertain the minimum antibiotic concentration necessary to provide "good commercial control" and to determine if it would be possible to admix antibiotics with fungicides and insecticides without reducing their individual effectiveness. Our greenhouse experiments during the preceding fall and winter had indicated that some antibiotic potency was lost in all combinations evaluated.

The orchards were located at Lexington and Savannah, Missouri, the ages of the trees were 9 and 15 years, respectively, and the variety treated was Jonathan. The plantings consisted of 3-row-groups of Jonathan, Red Delicious, Golden Delicious, and Winesap. The planting sequence was as follows: Jonathan, Red Delicious, Jonathan, Golden Delicious, Jonathan, Winesap, Jonathan, etc. Thus each 3-row-group of Jonathan trees was bordered by a relatively blight resistant variety.

The spray plot design was essentially the same in both orchards and appears in Figure 1. The first three sprays were applied at approximately 5-day intervals, and at 7 days for the subsequent ones. The four-spray program was included in these experiments as a secondary check since it was the spray schedule suggested for use to Missouri orchardists.

The standard fungicide at Lexington was a captan-zineb combination whereas the insecticides used were dieldrin in the first and second sprays and lead arsenate and D.D.T. in the fifth and sixth sprays. At Savannah the fungicide was sulfur paste with lead arsenate and D.D.T. added in the fifth and sixth sprays.

## Results

It was apparent almost immediately that blossom blight was exceedingly light. Blossom infections were observed to a limited degree in check trees and in trees of other varieties such as Red Delicious, Golden Delicious, and Winesap, which bordered the antibiotic sprayed-Jonathans but which were not themselves treated. In the antibiotic-treated Jonathans, blossom infections were virtually non-existent.

Considerable twig blight became apparent in both orchards approximately 2 to 3 weeks after full bloom and at Lexington this outbreak quickly reached epiphytotic proportions. It is to be noted that the antibiotic spray schedule had not terminated, at either orchard, when these twig infections were first observed.

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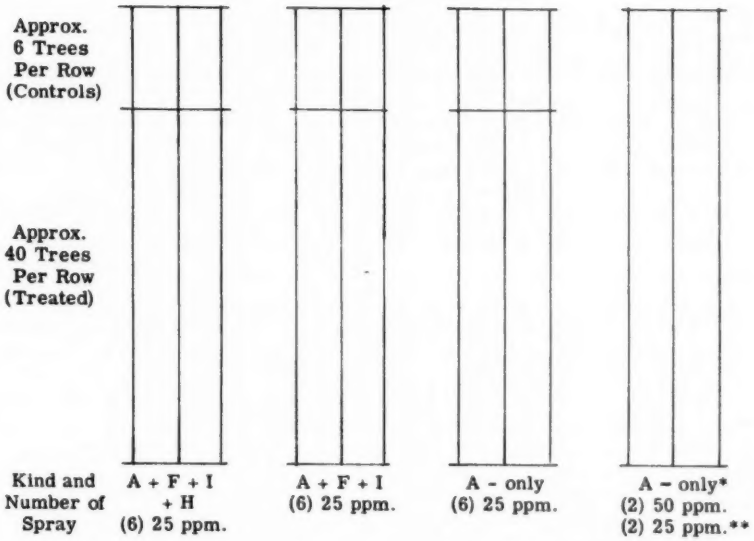
SPRAY PLOT DESIGN AT LEXINGTON, MISSOURI
1955


Approx. 6 Trees Per Row (Controls)
Approx. 40 Trees Per Row (Treated)
Kind and Number of Spray
A + F + I + H (6) 25 ppm.
A + F + I (6) 25 ppm.
A - only (6) 25 ppm.
A - only* (2) 50 ppm. (2) 25 ppm.**

LEGEND

A = Antibiotic (Agrimycin), F = Fungicide, I = Insecticide, H = Hormone (naphthyl acetamide at 15 ppm.)

* This 4-spray schedule is identical with the program suggested to commercial orchardists in Missouri.

** At the Savannah plots the concentration of each of the 4 sprays was 50 ppm.

FIGURE 1.

We have interpreted the data in Tables 1 and 2 as indicating poor control regardless of treatment. The consistent reduction in twig blight intensity in all treatments, as contrasted with the checks, may be explained, at least in part, by the larger number of blossom infections noted in the checks. In addition it should be pointed out that the data presented in Tables 1 and 2 are averages and that in all treatments there were trees that demonstrated a high degree of twig infection. Thus the difference between treatments may be more apparent than real. This is indicated by the lack of consistency between effectiveness of the same treatment in the two test plots.

Of particular interest was the observation that, almost without exception, a localized heavy infection of vegetative shoots in a given tree could be correlated to the reactivation of hold-over cankers, many of which were oozing freely. Later on secondary spread from these initially infected areas became so extensive that an accurate decision as to where the newer infections had come from could no longer be made.

In 1954, test plots at Boonville, Waverly, Lexington, and Savannah (1), which were sprayed with antibiotics, showed an exceedingly high degree of blossom blight control as compared with check trees. The vast majority of these trees remained completely free of blight for as long as 30 days after full bloom. Shortly thereafter twig blight became apparent in these previously blight-free trees. At that time it was postulated that these late infections had been caused by spread of inoculum from nearby infected unsprayed trees and from the untreated checks.

However, in the light of this year's developments, the question might be asked whether these late twig infections in 1954 were in reality primary infections caused by inoculum from reactivated hold-over cankers.

Table 1. Incidence of fireblight at Lexington, Missouri, 1955.

| Kind and Number of Sprays | A - only (2) 50 ppm (2) 25 ppm | A - only (6) 25 ppm | A + F + I (6) 25 ppm | A + F + I + H (6) 25 ppm |
|---|---|---|---|---|
| Avg. Number of cuts* per treated tree | 23 | 88 | 44 | 31 |
| Avg. Number of cuts per check tree | - - | 138 | 176 | 76 |

* Infected shoots were counted by the number of pruning cuts made. (Blight was cut out 5 times during the season and the data represent avgs. of totals for the 5 prunings.

Table 2. Incidence of fireblight at Savannah, Missouri, 1955.

| Kind and Number of Sprays | A - Only (4) 50 ppm | A - Only (6) 25 ppm | A + F + I (6) 25 ppm | A + F + I + H (6) 25 ppm |
|---|---|---|---|---|
| Avg. Number of Infections per treated tree * | 6.8 | 8.3 | 6.5 | 11.5 |
| Avg. Number of Infections per check tree | - - | 13.9 | 20.1 | 18.6 |

* Infected shoots were counted and left on the trees.

Is it not possible that fireblight in a given season might actually occur in two distinct waves, each being, technically, primary infection? -- the first wave occurring as blossom blight, and the second, late twig infection, resulting from bacterial ooze extruded from an infection initiated during the previous season and/or an internal extension of this old infection.

This contention was presented many years ago by Rosen (2, 3), who concluded from his data and observations that "mid-season twig blight" may be independent of blossom blight and that it is at least in part and perhaps wholly attributable to "overwintered" cankers that were left on trees.

It is suggested therefore that antibiotic sprays, although capable of providing a rather high degree of control against the blossom-type of infection, are relatively ineffective against the late or "mid-season" form of twig infection.

Thus the question raised by our experimentation of the past season is, how may late shoot blight resulting from hold-over cankers be reduced or eliminated? It is apparent that this must be accomplished in order to justify the use of antibiotic sprays and to maintain the high degree of control of blossom infection that they are capable of affording.

If hold-over cankers are primarily responsible for the late twig blight that has been reported by us and by others, then theoretically at least their removal by pruning should eliminate them as a source of inoculum. Yet there is some doubt as to whether or not intensive pruning is a practicable approach to this problem.

Prior to the recent work with antibiotics, no positive measures for fireblight control were available to the apple and pear growers in the central and eastern States. Sanitary procedures such as pruning were neglected by even the best orchardists and some of the reasons for their apparent apathy to pruning out old blight infections are as follows:

1. Pruning out old evidences of blight infections has not provided satisfactory blight control.

2. Removing all old blight from a young tree that had been severely infected might occasion the elimination of most of the new growth and bearing wood. Then, should blight ensue in the same tree the following season, the tree could be completely destroyed.

3. Fruit growers questioned whether all of the old infections could be found and removed by even the most conscientious worker. (We raise the question here whether or not it is possible that some late twig infections occur which do not manifest symptoms until the following season).

4. Many orchardists recognized the fact that only a small percentage of old cankers are ever reactivated and questioned their relative importance as a significant source of fireblight inoculum.

It is presumed that the high degree of blossom blight control afforded by antibiotic sprays might induce orchardists to resume their practice of carefully pruning out old fireblight infections. Finally, the data and observations presented herewith suggest that controlled pruning experiments conducted in conjunction with antibiotic spray programs may well answer the question that has been raised.

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# USE OF STREPTOMYCIN-PYROPHYLLITE DUSTS AGAINST PEAR BLIGHT AND WALNUT BLIGHT

Peter A. Ark

## Summary

Streptomycin-pyrophyllite dusts, unlike mixtures with bentonite, liberate sufficient streptomycin to afford a control of fire blight comparable with that obtained with wettable streptomycin spray or copper-lime dust. The pH of the pyrophyllite does not appear to influence either the liberation of streptomycin or stability of the dust.

The dust mixture gave somewhat less control of walnut blight than streptomycin spray but better than a copper A dust.

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The effectiveness of streptomycin against fire blight and other bacterial diseases of plants is now well established (1, 2, 3, 5, 7, 8, 9). In 1953 it was reported (1) that bentonite dust containing 240 ppm streptomycin base gave significant control of fire blight of pears in California. However, trials with bentonite-streptomycin dust, 240 ppm, in 1954, produced variable results, in most cases unsatisfactory. Later, in checking the release of streptomycin from this bentonite dust formulation, by eluting it with distilled water, it was found that no free streptomycin could be demonstrated by a laboratory assay method using standard antibiotic assay filter paper discs.

The fact that under certain conditions there was some benefit from this formulation led to investigation of the behavior of this dust in the presence of certain chemicals added to the water or the dust. It was found that the addition of 1% of dipotassium phosphate to the water, in which the bentonite streptomycin dust was eluted, liberated considerable amounts of streptomycin thus rendering the dust active against potential pathogens.

Further studies on dust carriers for streptomycin indicated that pyrophyllites are satisfactory diluents for streptomycin. That pyrophyllite can be of considerable importance in regulating availability of a toxicant was shown by Clayton and Grosso (3), who stated that phyrophyllite can be recommended as a diluent, while Fuller's earth and clay diluents are not satisfactory since they promote deterioration of the carbamate fungicide which they used to control blue mold of tobacco (Peronospora tabacina). It is also stated that a 20% zineb-tobacco dust gave less effective blue-mold control than a 10% zineb-pyrophyllite dust. To obtain equal blue-mold control the zineb-tobacco mixture would conceivably need to contain more than two times as much zineb. When an agricultural grade of streptomycin was mechanically blended with the pyrophyllites there was a free release of streptomycin where the dust was shaken in water.

Two pyrophyllites, one known as pyrophyllite ABB (pH4.6) and the other as Nuclay (pH8.1) were used to blend with streptomycin base at levels of 500 and 1000 ppm and employed in experiments to control fire blight of pear and walnut blight in 1955[1]. The performance of the dusts was checked by collecting numerous samples of dusted pear blossoms and bioassaying them for the presence of streptomycin in the receptables, the portals of entry for the fire blight organism, Erwinia amylovora. It was shown that there was a considerable quantity of available streptomycin present in the dusted flowers. Significant control of fire blight was obtained in the plots dusted with these new formulations of streptomycin where sufficient blight developed to measure in terms of the number of cuts per tree. In degree of control obtained, the streptomycin dusts compared favorably with the wettable form and copper-lime dust (Table 1), and at 500 ppm were superior to the copper-lime dust.

From the standpoint of economics, the dust formulations of streptomycin cost considerably less per acre than wettable formulations. Since the cost of streptomycin-pyrophyllite dust is from 8 (for 500 ppm) to 10 cents (for 1000 ppm) per pound, the cost of the material per acre of pears per application will vary from $3.20-$4.00 to $4.80-$6.00 where an average of 40 or 60 lbs. of dust per acre is applied. To cover the same area with a wettable form of streptomycin, using

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1 The writer wishes to express his gratitude to Dr. R. F. Phillips of Merck and Co., Inc., Rahway, New Jersey, for a very generous supply of streptomycin pyrophyllite (ABB) formulations used in the work here reported.

Gratitude is hereby expressed also to the Pacific Guano Fertilizer Co. of Berkeley, California for donating their labor and facilities in formulating Nuclay-Streptomycin dusts.

Table 1. Control of fire blight of pears in three different regions in California with wettable formulations of streptomycin, with streptomycin dust, and copper-lime dust. Summer, 1955.

| Treatments | Pear orchard 1 (Yuba Co.) | | Pear orchard 2 (Mendocino Co.) | | Pear orchard 3 (Lake Co.) | |
|---|---|---|---|---|---|---|
| | Number of trees treated | Cuts per tree | Number of trees treated | Cuts per tree | Number of trees treated | Cuts per tree |
| Check - no treatment | 82 | 0.21 | 169 | 0.29 | - | - |
| Streptomycin, 100 ppm (Agri-Strep). | 90 | 0.08 | 146 | 0.06 | - | - |
| Streptomycin, 100 ppm (Phytomycin). | 90 | 0.07 | - | - | - | - |
| Streptomycin-Pyrophyllite Dust, 1000 ppm. | 99 | 0.06 | 354 | 0.03 | 95 | 1.0 |
| Streptomycin-Pyrophyllite Dust, 500 ppm. | 99 | 0 | 263 | 0.06 | 95 | 1.0 |
| Copper-Lime Dust | 279 | 0.01 | - | - | 170 | 6.0 |

Dates of application for each orchard:

Orchard 1: Wettable streptomycin -- March 20, 24, 28, 30; April 5, 9, 14, 19, 22 and 27; May 2, 6, 12.

Streptomycin-pyrophyllite dusts -- March 19, 24, 29; April 2, 6, 11, 15, 18, 22 and 26; May 2, 7, 12 and 25.

Copper-lime dust -- March 21, 26, 30; April 7, 13, 20, 27; May 3.

Orchard 2: For all treatments -- April 2, 8, 15, 22, 30 and May 17.

Orchard 3: Dust formulations -- April 8, 13, 21, 27; May 5, 12 and 20.

Table 2. Control of walnut blight with copper and streptomycin at Linden Orchards, Linden, California. Summer, 1955. Treatments were made at early pre-bloom, middle of bloom, and post-bloom periods.

| Plot | Treatment | Number of trees | Disease (percent) |
|---|---|---|---|
| 1 | No treatment. Check | 150 | 24.6 |
| 2 | 10% Copper A dust; 30 lbs./Acre | 42 | 11.6 |
| 3 | Streptomycin (Agri-Strep)-Pyrophyllite (ABB) dust, 1000 ppm, 50 lbs./Acre | 42 | 7.6 |
| 4 | Streptomycin (Agri-Strep)-Pyrophyllite (ABB) dust, 500 ppm.; 50 lbs./Acre | 42 | 5.9 |
| 5 | Streptomycin wettable (Agri-Strep), 50 ppm. | 56 | 2.7 |

100 ppm, where on an average 700 gal. of spray is used, will require the expenditure of 60 dollars, if the price of streptomycin is maintained at 20 cents per gram. With more intensive studies on various carriers and dust amendments to facilitate faster liberation of the streptomycin and its penetration into plant cells (6) streptomycin dusts may become an efficacious and economical means of controlling many bacterial diseases of plants.

Streptomycin dust formulations controlled walnut blight (Xanthomonas juglandis) better than copper dust (Table 2). However, the wettable form of streptomycin gave a better control of walnut blight than the dust formulations. While no explanation for this discrepancy can be offered at this time, it may be significant that adherence of the dust particles to walnut surfaces was not satisfactory and the dust was observed to be easily detached by wind.

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# NUT DISEASES IN OREGON IN 1955

P. W. Miller[1]

## WALNUT DISEASES

Walnut Blight (Xanthomonas juglandis (Pierce) Dowson) was widely distributed in Oregon in 1955; however, it was not generally so severe this year as in 1954. It is estimated that not more than 5 percent of the 1955 crop was destroyed by this disease.

Mushroom Root Rot (Armillaria mellea (Fr.) Quel.) caused the decline and the death of a number of Persian walnut trees (Juglans regia) grafted on both Hind's black walnut (Juglans hindsi) and Persian walnut rootstocks in 1955. As in 1954, the incidence of mushroom root rot was greater in the upland orchards and in those on the poorer soil types than in orchards in the river bottoms on the better soil types.

Crown Rot (cause undetermined). A crown and collar rot of undetermined cause was found affecting a limited number of Persian walnuts grafted on Hinds black walnut rootstocks and some Persian seedling walnuts. Attempts to isolate a Phytophthora sp. or some other parasitic organism were uniformly negative.

Downy Spot (Microstroma juglandis (Bereng.) Sacc.). This leaf spot occurred in limited amounts in a few walnut orchards in the Willamette Valley in 1955. It was of no economic importance, however, since it did not cause any defoliation or decrease the functional leaf area appreciably.

Phyllosticta Leaf Spot (Phyllosticta juglandis (DC.) Sacc.). was found in one orchard in the Willamette Valley. However, this leaf spot was of little or no economic importance, as it did not reduce the functional leaf area significantly or cause premature defoliation.

Leaf Scorch (non-parasitic). This leaf disorder was widely distributed in western Oregon in 1955, occurring to a greater or less extent in most Persian walnut orchards in the western part of the State. It was generally more prevalent and severe than in 1954.

Black-line (Girdle) of Grafted Walnuts (non-parasitic). This disorder was responsible for the death of more Persian walnut trees grafted on black walnut roots in Oregon in 1955 than all other causes combined. It was found to be widely distributed in Oregon, occurring to a greater or lesser extent in practically all walnut-growing districts in the State. In general, incidence was greater in the upland than in the river bottom soils. It was more common in the Franquette than in the Mayette or Parisienne grafted on black walnut rootstocks.

One case of black-line was found on what appears to be a Paradox-hybrid, a cross between a Persian and black walnut. Not a single case of this disorder was found in Persian walnuts grafted on pure Persian walnut rootstocks.

## FILBERT DISEASES

Bacterial Blight (Xanthomonas corylina P. W. Miller et al.) was widely distributed in western Oregon in 1955. It occurred to a greater or lesser extent in practically all filbert orchards in the State. It was most prevalent in orchards in the northern part, where it caused the death of many small twigs and branches.

Mushroom Root Rot (Armillaria mellea (Fr.) Quel.) was found causing the decline and death of a few filbert trees in the northern part of the State in 1955.

Crown Gall (Agrobacterium tumefaciens E. F. Sm. & Towns.) Conn was found on one filbert tree near Eugene, Oregon in 1955. It caused an aerial gall and a large "witches-broom" on one limb.

Powdery Mildew (Phyllactinia corylea Karst.) occurred to a greater or lesser extent in numerous filbert orchards in western Oregon in 1955. However, it was of no economic importance as it did not make its appearance until near the end of the season and the leaves persisted on the trees until the time of normal leaf fall.

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Brown Stain (non-parasitic). This disorder, characterized by exudation of a brownish liquid from the shell and abortion of the embryo, was present in limited amounts in 1955 in a number of orchards in Oregon. However, crop losses were insignificant.

Arsenical Leaf Injury. A browning of the top surface of the leaves, due to arsenical injury and accentuated by relatively high temperature, was very prevalent in western Oregon in 1955. It was worse in orchards where aphids and aphid honey-dew were very abundant.

HORTICULTURAL CROPS RESEARCH BRANCH, AGRICULTURAL RESEARCH SERVICE, U. S. DEPARTMENT OF AGRICULTURE, OREGON STATE COLLEGE, CORVALLIS, OREGON

# CYTOSPORA DAMAGE IN IDAHO PRUNE ORCHARDS[1]

A. W. Helton[2] and J. A. Moisey[3]

## INTRODUCTION

Fungi of the genus Cytospora have been present in Idaho and reported in the literature for many years. However, no record of their occurrence in the State on apricots or prunes has been found before 1951. In July of that year an infected Italian prune orchard was discovered, but the identity of the disease was not known. During the same season, unmistakable Cytospora cankers were found on sweet cherries.

The disease observed on Italian prune in 1951 was found again in several areas in southern Idaho on the same variety in 1952, and more seriously on the President prune. Preliminary isolations made the following year suggested that the causal agent was a member of the form-genus, Cytospora. Subsequent work in 1953 and 1954 established identity as Cytospora and the similarity as well as variability of isolates from widely separated orchards. More recent surveys have revealed that the Cytospora disease is present also on cherries, peaches, apricots, apples, and willows. It is quite likely that other hosts are affected.

Idaho was without the services of a fruit pathologist from 1945 to 1951. Since there seems to have been no report of this disease in prunes prior to 1954, and since the damage was found to be so widespread and severe in 1951 through 1954, there appear to be only three plausible explanations. Aggressively virulent strains of Cytospora may have been brought into Idaho early in, or just preceding, that period; or mutation and rapid spread of strains already present occurred because of some factor or factors unknown; or widespread infection occurred following the severe winter injury sustained in 1948 and 1949, with ever increasing virulence of the fungi taking place thereafter. All may be involved.

As early as 1951 growers were beginning to seek help because of serious damage in prune orchards by strains of Cytospora. Requests for aid have come in at irregular intervals since that time, and are continuing to come in from areas considered to be "hot spots". There seems to be imminent danger of continued spread into areas thus far relatively free from the disease, in which case the industry faces a new problem. The possibility of continued profitable production of prunes especially the Italian variety, already has been questioned in some parts of Idaho, because of the many conditions leading to deterioration in orchard trees. If the Cytospora damage continues unchecked, growers in seriously affected areas will very likely turn to other crops.

## VARIETIES AFFECTED

Field observations made thus far indicate that Cytospora can be found in most of our tree fruit varieties, especially apple, prune, cherry, and to some extent apricot and peach. Apricot acreage in Idaho is low, and detailed surveys of this crop have not yet been made. It is suspected that many of the cankerous conditions in Idaho peach orchards previously diagnosed variously as winter injury, old Coryneum or brown rot cankers, etc., may actually prove to be caused by species of Cytospora.

Previously unrecognized is an apparent strain specificity of a kind which tends to limit infection of certain varieties to certain strains of the fungus. Preliminary host range studies conducted thus far indicate also that Cytospora, as found in Idaho, is not merely an invader of dead and dying wood as it has mostly been described to be.

## SEVERE PRUNE DAMAGE AREAS

Cytospora canker on Italian prune was first observed in the Parma area near Homedale. This was in 1951. The following year a severely infected President orchard was found in the Sunny Slope area near Marsing. This orchard was adjacent to an Italian orchard where no evidence of Cytospora infection was observed. The President orchard, on the other hand, had a

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[1] Published with the approval of the Director as Research Paper No. 407 of the Idaho Agricultural Experiment Station.

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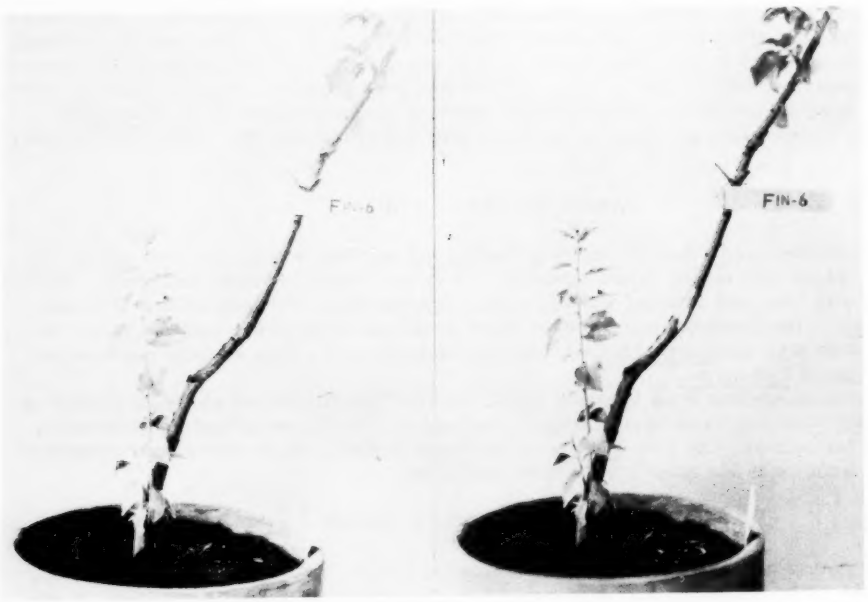
FIGURE 1. Above: A canker which developed in the trunk of a two year Myrobalan plum seedling after inoculation with a Cytospora isolated from an Italian prune canker. Girdling is almost complete, yet the parts of the tree terminal to the canker showed little effect, and the necrotic margin of the canker (see shaved portion) had progressed only a short distance. This was an August inoculation in a field plot.

Below: A potted Myrobalan plum seedling in the greenhouse after inoculation with a Cytospora culture obtained from an Italian prune canker. The inoculation point is halfway between the tag and the soil line.



multitude of cankers, both young and old, on most of the trees adjacent to the Italians. Some of the President trees already were dead; many had been variously and severely pruned by the grower in the removal of dead wood; and many were so damaged that death seemed imminent. Now, after 4 years, the grower has conceded loss of the President orchard, and moderate damage has appeared in the Italians.

In 1953 several seriously affected orchards of both Italian and President varieties were found in the vicinity of Fruitland. In 1954 slight evidence of Cytospora infection was observed for the first time in the Emmett area. A preliminary survey in May of 1955 resulted in the location of extremely severe cases near Payette in which most of the trees in the orchards were affected. In one case the grower had interplanted with new President trees, inviting their destruction.

Results of these orchard surveys, which were only preliminary, led to the conclusion that most of the western part of southern Idaho could be considered a "hot spot" insofar as Cytospora infestation and danger of spread are concerned.

## RESULTS OF INVESTIGATIONS CONDUCTED THUS FAR

Considerable preliminary work on isolation of the pathogens involved and reproduction of the disease has been done at Moscow. Results thus far have established reasonably well that the original concept as to the secondary nature of Cytospora is outmoded. Other than this, there has been limitless confusion. Inoculations made in the field at one time of the year often do not react exactly like those made at other seasons or under other conditions. The inoculation technique also seems to have a bearing on results, as do several other factors.

In 1954 five isolates were taken from representative prune field symptoms, grown to the same age on the same medium, and used in duplicate proof-of-pathogenicity studies and host range investigations. Variation was noted in both degree of virulence and in host selectivity. The preliminary host range study may be summed up by the statement that all isolates were severely pathogenic on peach and apricot but produced no reaction at all on apple or Mazzard cherry. Seedlings were used in all cases for the host range study. Mahaleb cherry suffered considerable damage, but an odd circumstance apparent so far is that although severe Cytospora cankers can be found on sweet cherry in the field, all five isolates failed completely to infect sweet cherry seedlings. Also, although Cytospora occurs on apples in Idaho, all five isolates failed to infect apple seedlings. Pear seedlings were parasitized in some cases.

Inoculation was done by inserting an agar block containing the actively growing fungus into a downward and inward slanting cut made through the bark and into the xylem, and binding firmly with rubber budding strips.

With one exception Myrobalan plum seedlings developed severe cankers (Fig. 1), as did the few inoculations of Italian and Weatherspoon prunes. These, however, were primarily cankerous and did not produce wilt except in one case. Wilt symptoms appeared in a few days in Lovell peach seedlings (Fig. 2), almost as soon in Tilton apricot seedlings (Fig. 3), and more slowly in Mahaleb cherry seedlings.

Preliminary sectioning of diseased wood did not yield evidence of mechanical plugging sufficient to cause wilting. Therefore a toxin is suspected, one that moves rapidly toward the terminals and slowly, if at all, toward the base of the tree. Lovell peach trees that were dead in the aerial wilted portions were cut off below the lowermost margin of the necrosis, after which new shoots came out below the cut and grew normally.

A cultural study conducted under as nearly constant conditions as possible showed a variation of the fungus (Fig. 4) that was similar in effect to the variation in host reaction. Much saltation or cultural mutation was observed in which the fungous growth became sectored into various "pie shapes" (Fig. 5 and 6). It is suspected that pathogenicity of the fungus in these variant areas differs also, although supporting evidence has not been obtained. If this were so, inconsistent choice of spots in the culture for removing inoculum for pathogenicity studies could result in inconsistent results.

The immediate question arising at this point is, did this sort of mutation result in the complex and peculiar disease picture we now have? For example, can it explain why a President orchard adjacent to an Italian orchard, without even a fence between is severely damaged, whereas the Italian variety is practically untouched for several years (Fig. 10)? Also, does it account for the apparent immunity of certain varieties to the isolates tested, even when those varieties have been known to be susceptible to Cytospora invasion? The questions are many,

FIGURE 2. Two Cytospora isolates from prune cankers caused the wilt, die-back, and decline in the Lovell peach seedlings (A, C) on both sides of the check (B).

FIGURE 3. Wilt and die-back in Tilton apricot seedlings caused by cultures of Cytospora isolated from prune cankers.

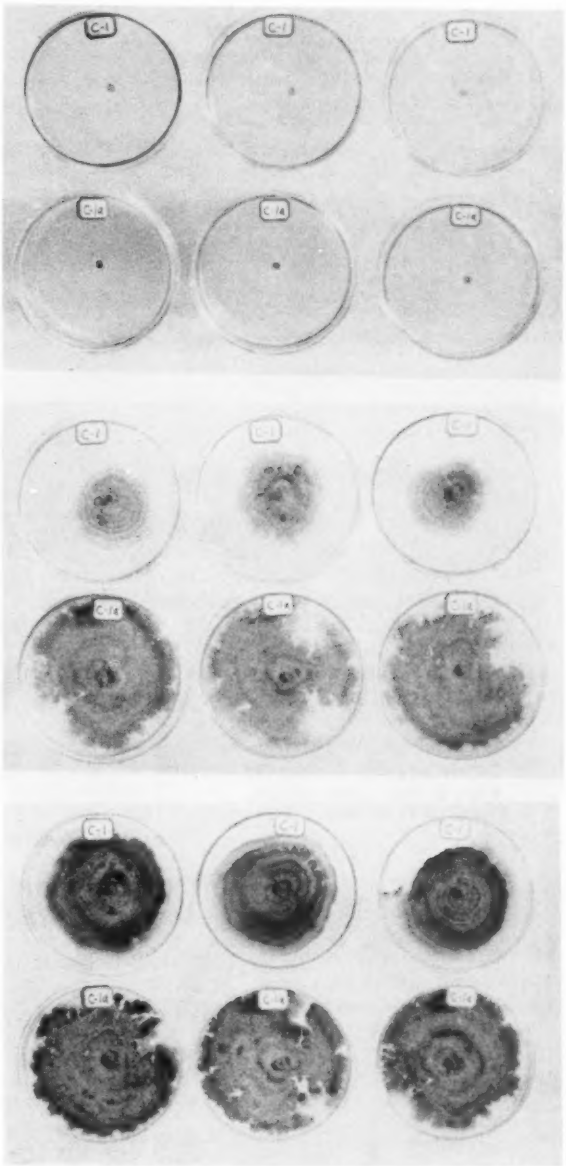


FIGURE 4. The original (C-1) Cytospora isolate obtained from an Italian prune canker and the re-isolate (C-1a) obtained from artificially infected Myrobalan plum (above). The cultures are three (above), five (center), and seven (below) days old. Note growth variations and growth differences beginning to show after five days; also, that some of the re-isolate cultures (C-1a) have developed much more erratic and rapid growth habits.

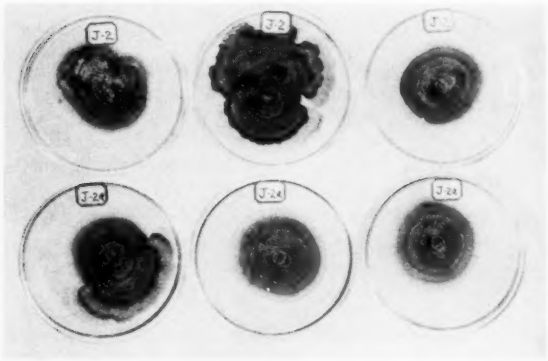


FIGURE 5. Some cultural characteristics of a Cytospora isolate obtained from a canker on President prune. The medium is potato-dextrose peptone agar. J-2 is the original culture; J-2a is the re-isolate obtained from the disease reproduced in Myrobalan plum. Note the variation in both J-2 and J-2a plate to the left. The cultures are seven days old; all are of the same age.

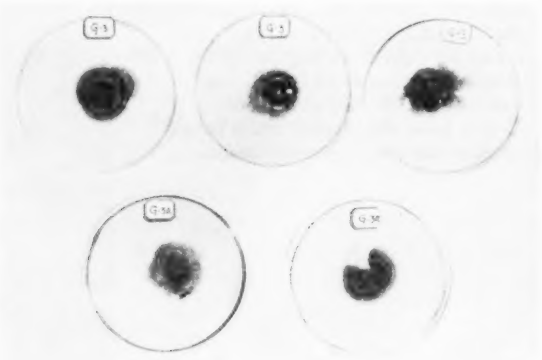


FIGURE 6. The original Cytospora isolate (G-3) obtained from an Italian canker and the re-isolate obtained from the reproduced disease in Myrobalan (G-3a). Cultures are eleven days old. There is an obvious mutation in the G-3a plate to the right (white segment) and less obvious ones in the other plates.

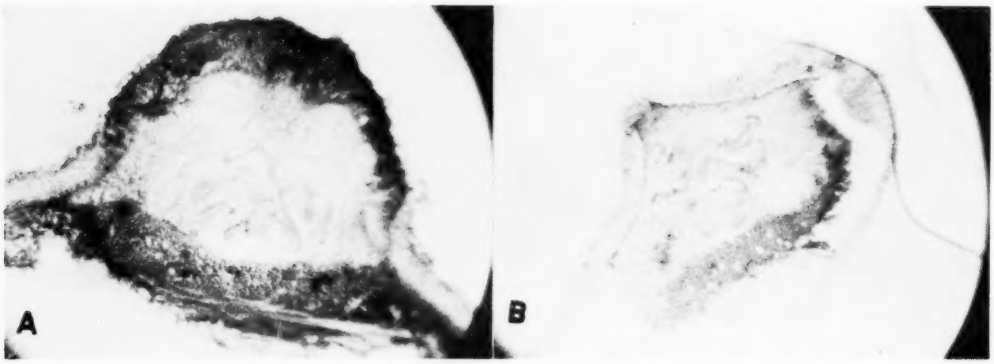



FIGURE 7. Sections through pycnidial stromata showing the many randomly arranged pycnidial cavities before rupture (A) and after the pore is formed (B) through which the spore tendril is extruded.

FIGURE 8. Young President prune orchards being decimated by Cytospora canker.
A -- Note the serious die-back of the tree to the right, and the general decline of most of the others. The tree in the left foreground was the best in that section of the orchard.
B -- Absolute destruction, with pruned off wood piled for burning.

and answers in most cases are not yet available. But that Cytospora is capable of primary infection and extreme virulence is no longer in doubt in Idaho.

## FACTORS LIKELY TO AFFECT CYTOSPORA DAMAGE

Investigations have not progressed far enough to reveal the precise predisposing factors active in Idaho orchards. Until such information is accumulated, there can only be speculation, based somewhat on previous knowledge of the behavior of Cytospora, recognizing, however, that we may be dealing with different strains, and therefore, possibly, with different predisposing factors.

Ordinarily the practical pathologist thinks in terms of wound reduction for reduction of infections. Any sort of damage to the tissues can be considered wound damage, whether it be weather, (hail, sunburn, freeze cracking, wind breakage, or snow breakage), cultural (pruning, spraying, cultivation), or other. This is not meant to exclude those diseases, pests, and other abnormal conditions that tend to weaken the trees or reduce their thriftiness (e. g., faulty irrigation, fertilization, thinning, etc.) and hence their resistance to injury by various agencies. All these things have been recognized as being contributory factors in the orchard tree decline due to Cytospora. Now, however, it is becoming ever more obvious in Idaho that a tree need not be unusually low in vigor to be invaded by Cytospora, which makes wounds associated with normal growth, i. e. pruning, spraying, and cultivation, of prime importance.

Wounds in cultivation can be avoided. In an orchard where optimum productivity is desired, pruning wounds cannot be. Nevertheless, it is possible to modify the pruning practice, and by this means obtain a reasonably satisfactory preliminary control or spread-supression measure. This is particularly true when trees are not only pruned correctly from the horticultural viewpoint, but in such a manner that orchard equipment can move through with a minimum of result-

FIGURE 9. Progress of the Cytospora disease in Italian prune trees showing early wilting and flagging (A), second-year branch die-back (B), and final stages of tree death (C).

FIGURE 10. Varietal difference in reaction to certain types of Cytospora is illustrated here in the total destruction of the President trees to the right and the absence of pronounced effects in the Italian trees to the left. The photograph was taken from a position on the dividing line between the orchards.

ing branch wounds. In affected orchards, such wounds quickly become infected.

Whether lenticels can serve as entry pathways is as yet unknown, but if the fungus can invade through natural openings, such as the lenticels or leaf scars, modification of pruning practice will lose much potential significance. A further possible complication is suspected, in that the fungus might be more active during the pruning season than at other times, though this would have little effect on lenticel invasion.

## SYMPTOMS ASSOCIATED WITH CYTOSPORA

Several symptom types are associated with Cytospora infection in Idaho orchards. Attention was first directed to the disease in Italian prunes in 1951 because of the dead flags, or discolored terminals, scattered over the trees, which resulted when cankers developed on the twigs and killed the parts terminal to the cankers (Fig. 8 and 9). Often the killing was so rapid that the leaves failed to drop off, but drooped, turned brown, dried up, and continued to hang on the trees instead. Thus the tell-tale yellow to brown flag developed, much as the colored flag in a pear tree indicates the presence of a fire blight canker somewhere below it.

Sometimes there is a tendency of the parts terminal to the canker to show a wilt or semi-wilt condition as death approaches (Fig. 9, A). This also results in a betraying flag of abnormal appearance, whether or not serious color change is involved, and is particularly striking when viewed from a distance. Often the leaves are slow in appearing in the spring, of small size, and pale in color. This is especially prominent in orchards suffering from the all too common zinc deficiency.

At other times there is little or no indication of abnormal color in the foliage terminal to stem cankers. In these cases the terminal parts apparently fail to set buds, and hence do not leaf out the following spring. Instead they usually have died during the winter (Fig. 11).

Of the cankers themselves, there seem to be several types in Idaho, influenced by varietal characteristics. The most common type in Italian prune in some areas, and to some extent in President, is decidedly erumpent and gummy (Fig. 13) from the time that it is very small on the twig and does not obviously affect terminal parts until advanced stages. In some cases the most prominent cankerous disorder associated with Cytospora infection of Italian prune is an extremely elongated necrotic streak condition in which the bark does not rupture. Some such cankers have been found that have apparently expanded from a lateral into a major branch where the streaks progressed rapidly toward the base of the tree and only very slowly toward the tip (Figure 12, A-C). This is in direct contrast basically to behavior noted in experimentally inoculated trees, in which the parts terminal to cankers in some varieties were rapidly killed, but spread downward was very slow. The significance of this has yet to be established. This same sort of streak symptom more often moves downward from the terminals (Figure 11, A-C) or from closely below them, but the margin always is darkly necrotic and often is prominently zonate. It may be due to a reaction that is primarily toxin response.

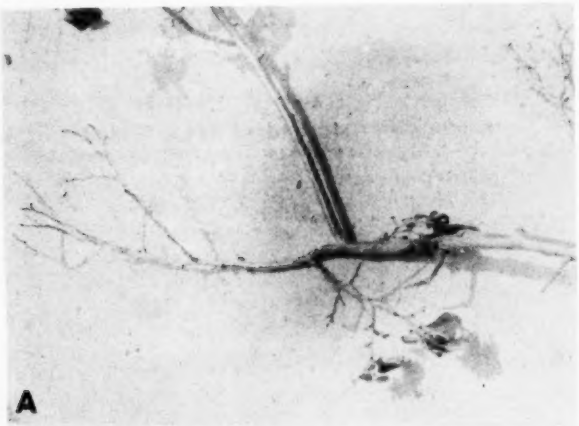
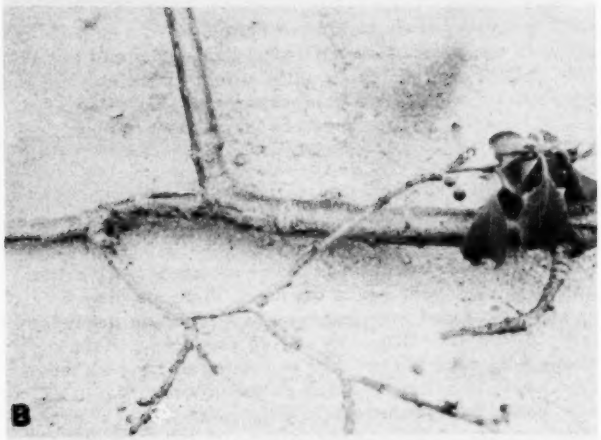
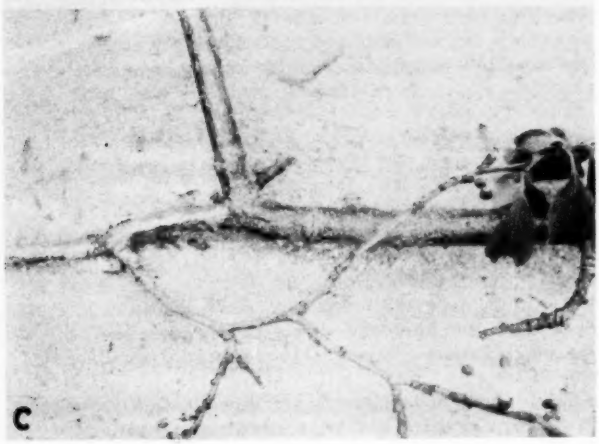



FIGURE 11. A--Die-back often associated with Cytospora. Such twigs sometimes are killed quickly, showing flags of dead leaves hanging on the tree during the season but looking like this the next. Such symptoms generally progress downward along the branches, killing the tissues, laterals, etc., with a streak type of necrosis.




B--A close-up of the marginal area of the branch. Close observation reveals the margin line between the two laterals.




C--The bark has been shaved to show the streak type of necrotic margin. The necrosis has destroyed all of the terminal of the branch down to the smaller lateral which it has bypassed. The similarity in size of the larger lateral and the main portion of the branch indicates that the streak has moved down only slowly in this case, or that it began to move down quite some time after initial infection.

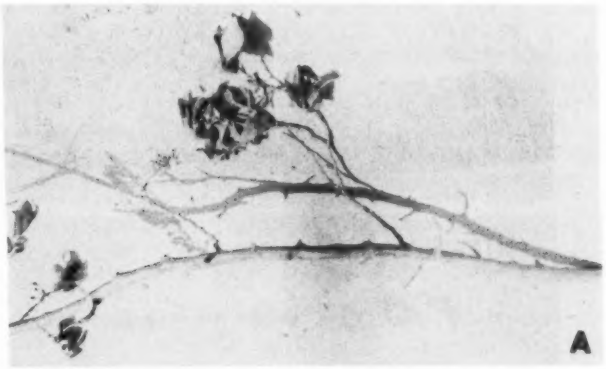
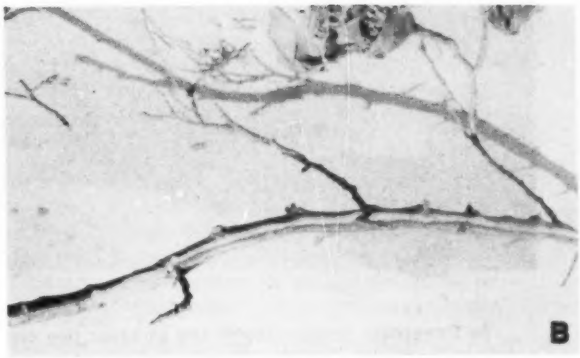
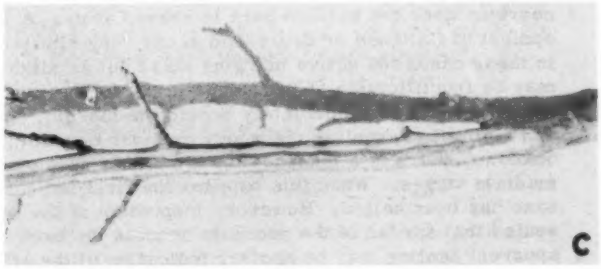



FIGURE 12. A -- A streak canker that apparently began in the dead stub of a twig farthest to the left and has moved downward almost to the right edge of the photograph. The depressed margins of the streak can be followed by close inspection of the side of the branch opposite the live laterals.




B -- The shaved apical portion of the streak. Note that the margin of the necrosis ends on the apical side of the twig.




C -- The shaved basal portion of the streak. Note that the necrosis seems to be progressing downward independently of any lateral twig influence.

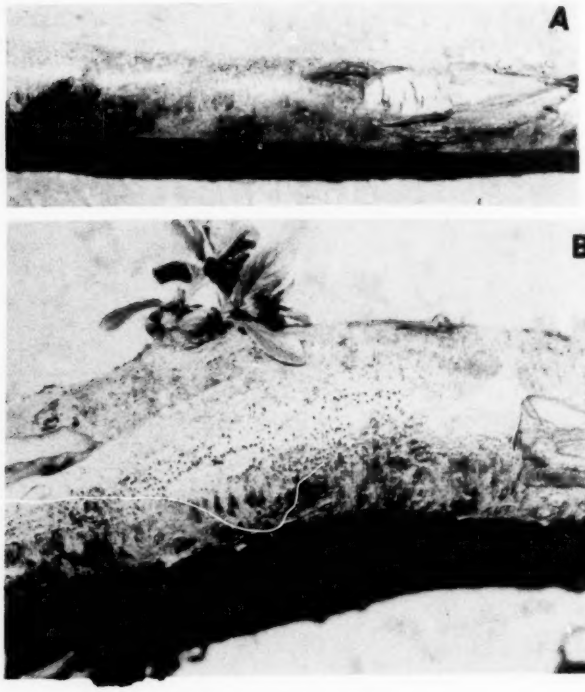



FIGURE 13. A--A Cytospora canker in a three inch President prune branch. In this case the canker is moving downward from the area where the bark has cracked, shredded, and sluffed away. In the lower part of the photograph there are several gum spots which often are associated with such cankers in Idaho prune orchards.

B--A fruiting Cytospora canker on a President prune branch showing rapidly moving necrotic margins. In Idaho it is unusual to find pycnidial pustules in so recently killed tissues.

In President prunes there are at least two types of reaction in the field besides the foliage effect already described. These concern stem cankers (Fig. 13). The canker generally is more severe in this variety than in Italian. Early in its development, the canker is darkly necrotic when the surface bark is shaved away. A little later there is a tendency toward development of flattened or depressed areas very similar in appearance to bacterial gummosis cankers. In these cases the active margins stand out as slight ridges in the bark. Subsequently, there may be fructification of the fungus in the form of pycnidial pustules (Fig. 7, 13), but this does not always occur immediately behind the margin. In old cankers the bark tends to split, shred, and sluff off, revealing the woody cylinder beneath (Fig. 13). Sometimes, for reasons as yet unknown, there is a tendency toward callus development at the canker margins during intermediate stages. When this happens the first impression gained is that the progress of the disease has been halted. However, inspection of the same cankers on successive years has revealed that spread of the necrosis beneath the bark has continued at a considerable rate. The apparent healing may be another indication of the effect of environmental conditions or it may indicate a peculiar temporary loss of virulence. The real reasons have yet to be determined.

Experimentally produced symptoms in seedling nursery trees vary widely, as indicated above. Most isolates have caused cankers on Myrobalan plum resembling field prune symptoms, but wilting of Myrobalan is infrequent.

None of the isolates tested thus far have shown any reaction on apple seedlings, which is surprising since Cytospora on apple is common in the field. This is true also to some extent for Mazzard, or sweet cherry seedlings.

Mahaleb cherries were affected to the extent that cankers were produced, sometimes in serious proportions. Occasionally, severe wilting developed. Pear seedlings were affected similarly but did not develop wilt symptoms.

Tilton apricot seedlings were very susceptible to all isolates. Rapidly spreading cankers were formed in a short time. Rapid wilting of parts terminal to the cankers was common.

Reaction to all isolates was most severe in Lovell peach seedlings. Parts terminal to in-

oculation points wilted and died within a few days. This developed so rapidly that canker margins were difficult to find and follow. The reaction was most suggestive of acropetally translocated toxin. Trees that were dead above the lowest inoculation point produced new shoots when cut off less than an inch below that point. Such shoots grew normally for indefinite periods.

## CURRENT CONTROL RECOMMENDATIONS IN IDAHO

The fungus seems to be most active during periods when pruning normally should be done, and pruning wounds may well be functioning as prime entry points. Natural wounds in the form of leaf scars may act as entry pathways. Whether the fungus is capable of entry through lenticels is not known but this is considered unlikely. If subsequent investigations reveal that lenticel or leaf scar entry does occur, it will be evident that development of a good control program will be difficult indeed.

It is suspected that winter injury is an important factor in providing entry points. This can be reduced by many standard procedures.

The effect of sprays is unknown, but chemical control by itself is not likely to be successful. The cankers are too deeply seated and the fungus too versatile. Rather than investigation of control materials that can be used in the form of sprays, efforts in Idaho are being devoted to learning exactly how the various strains behave in their native environment. An important phase concerns intervarietal strain relationships. Definite information of this kind is imperative in the formulation of a control schedule for mixed fruit-growing areas. Thus far it appears that previous concepts of the nature and behavior of Cytospora can be accepted only with considerable caution.

As the matter now stands, it is suggested that the grower prune out all suspicious parts during the usual pruning season, thoroughly but wisely. Cutting wisely means cutting closely and cleanly. When the cut is made, painting with a good disinfestant such as Bordeaux paint is suggested. It is recommended that the pruning tools be dipped in a disinfesting solution carried at the grower's convenience, perhaps on a tractor. It is suggested, also, that a trailer be attached to the tractor and that all pruned-off material be placed on it, hauled out of the orchards, and destroyed by fire. This advice is issued in severe cases. In lesser cases it can be moderated.

When all this is said, the grower is reminded that such measures, drastic though they are, do not constitute cures; that Cytospora can and will come in from neighboring orchards or even from wild hosts nearby; or perhaps from considerable distances also that maintenance of a good disease control program for the common diseases will help, because a fungicide covering on the trees at all possible times constitutes additional insurance when the spores are abundant. He is encouraged to follow all recommended cultural practices for maintaining his orchards in optimum condition.

Thus far, orchard removal has been recommended only in rare cases.

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# THE EFFECT OF PESTICIDES ON THE FLAVOR OF CANNED PEACHES[1]

L. O. Van Blaricom, H. H. Foster, and C. D. Evans[2]

## SUMMARY

Relatively few fungicides tested produced an off-flavor in canned peaches. During the course of the investigation the following fungicides induced off-flavor to some degree: 1) Experimental fungicide, Rohm and Haas CR-305 produced a marked off-flavor which was highly significant. 2) The use of the sulfur-urea combination fungicide resulted in poorly flavored peaches, but this off-flavor was attributed to the delay in fruit maturation. 3) Captan gave some evidence of inducing off-flavor during 1952. However, canned peaches which were orchard sprayed with Captan in 1951 and 1953, were rated as good to excellent in flavor. The adverse flavor noted in 1952 was assumed to be due to the diluent used or to impurities in the formulation of Captan. 4) Other fungicides tested including experimental materials failed to produce significant off-flavor.

## INTRODUCTION

Very little information is available concerning the effect of fungicides on the flavor of peaches with the possible exception of sulfur, which has been generally used as a fungicide in spray schedules for peaches. Sulfur has been used as a check or control lot in studies of pesticides and their effect on the flavor of peaches. Smith, et al. (8), used the fungicide, Phygon, in combination with parathion, with no adverse effects on the flavor of canned peaches.

In contrast to the lack of information concerning the effect of fungicides on the flavor of peaches, there are several reports on off-flavors produced by insecticides. The use of benzene hexachloride has apparently resulted in the most pronounced off-flavors. Snapp (9, 12), Smith, et al. (7), and Gilpin, et al. (4), have reported off-flavors in fresh peaches from the use of benzene hexachloride when used too near the time of harvest. The adverse effect of benzene hexachloride is increased when peaches are canned, as reported by Bailey, et al. (1), Cochran and Van Blaricom (2), Davis (3), Gilpin, et al. (4), Gould, et al. (5), and Smith, et al. (7). However, Smith, et al. (8), found no pronounced effect from benzene hexachloride when used in the first two sprays only.

Several other insecticides have been reported on, but their effects on flavor are very small or none at all. Among those tested are: Aldrin (9), Chlordane (2, 5, 7, 8, 9, 10, 11), DDT (9), Dieldrin (9), HETP (10, 11), Malathion (6), Methoxychlor (9), Parathion (2, 7, 8, 9, 10, 11), TEPP (10, 11), and Toxaphene (7, 10, 11).

## METHODS

This report presents data for the period of 1950 through 1953. The peaches tested in the taste panels, unless otherwise stated, were sprayed at approximately 600 pounds pressure, using a four-nozzle spray gun. After harvesting, the peaches were canned at the Horticultural Products Laboratory at Clemson College. In 1950 the taste panel consisted of 21 unselected male students at Clemson. During 1951, 1952, and 1953, 10 male students were selected for the taste panel after preliminary tests indicated their reliability in judging samples. The samples were taste rated on the basis of 1 to 10. In most cases the number of samples taste tested at one time were limited to 4 or 5, although in some cases as many as 7 samples were used. The scores were evaluated by analysis of variance. When the sample was markedly off-flavor, no further tests were made. However, when the off-flavor was slight or questionable, paired and triangular taste tests were conducted.

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[2] Respectively, Associate Food Technologist, Associate Plant Pathologist, and formerly Assistant Agricultural Economist, South Carolina Agricultural Experiment Station.

Table 1. Effect of fungicidal sprays on the flavor of canned peaches.

| Sprays[a] | Concentration per 100 gals. | No. of Applications per season | Field Plots Tested | Years Tested | Effect on Flavor |
|---|---|---|---|---|---|
| 1. DuPont, Manzate (Maneb) | 2 lbs. | 7-8 | 3 | 1 | None |
| 2. Cal. Spray Chem. Co., Captan (Orthocide 406) | 2-4 lbs. | 6-8 | 12 | 3 | Slight off-flavor in 1952. No off-flavor in 1951 nor in 8 lots in 1953. |
| 3. Cal. Spray Chem. Co., Ortho Special M | 2 lbs. | 7 | 1 | 1 | None |
| 4. Cal. Spray Chem. Co., Ortho HL-673 | 3 lbs. | 7 | 1 | 1 | None |
| 5. R & H, CR-305 | 2 lbs. | 5 | 1 | 1 | Decided off-flavor developed. |
| 6. R & H, CR-2379 | 2 lbs. | 8 | 1 | 1 | None |
| 7. R & H, L. O. 737 | 2 lbs. | 7 | 1 | 1 | Slight off-flavor. |
| 8. R & H, L. O. 738 | 2 lbs. | 7 | 1 | 1 | None |
| 9. R & H, Tniram | 4 lbs. | 7 | 1 | 1 | None |
| 10. R & H, D-14, with Ferric Sulfate | 1½ qts. 6 lbs. $FeSO_4$ | 8 | 1 | 1 | None |
| 11. R & H, D-14, with Manganese Sulfate | 4 qts. 1 lb. $MnSO_4$ | 8 | 1 | 1 | None |
| 12. C & C, Glyodin (Craig 341) | 2-3 lbs. | 2-5 | 1 | 1 | None |
| 13. C & C, 341, S. C. | 2 lbs. | 5 | 1 | 1 | None |
| 14. C & C, 5379 | 2 lbs. | 6 | 2 | 1 | None |
| 15. C & C, 5400 | 2 lbs. | 6 | 2 | 1 | None |
| 16. Shell Chem. Corp., Shell XP-90 | 4 lbs. | 7 | 1 | 1 | None |
| 17. Clorox (Sodium Hypochlorite) | 2 lbs. | 5 | 1 | 1 | None |
| 18. (HTH) Calcium Hypochlorite | ½ lb. | 8 | 1 | 1 | None |
| 19. Mathieson Chem. Corp., Sulfur, dispersible | 3 lbs. | 8 | 1 | 1 | None |
| 20. Sulfur, wettable | 4-12 lbs. | 5-8 | 24 | 4 | None |
| 21. Sulfur, wettable, with neutral Zinc | 6 lbs. Sulfur 2 lbs. Nu. Zn. | 6 | 2 | 2 | None |
| 22. Sulfur, wettable, with neutral Manganese | 6 lbs. Sulfur 3 lbs. Nu. Mn. | 6 | 1 | 1 | None |
| 23. Sulfur, wettable and Urea | 6 lbs. Sulfur 5 lbs. Urea | 8 | 1 | 1 | Decided off-flavor, probably due to immaturity. |
| 24. Parathion | 1.5-2 lbs. | 5-7 | 8 | 3 | None |
| 25. Gen. Chem. Co., 1189 | 2 lbs. | 8 | 1 | 1 | None |

[a] Suppliers and chemical names of fungicides:

1. E.I. DuPont De Nemours & Co. -- manganous ethylenebis (dithiocarbamate).

2, 3, 4. California Spray Chemical Co. -- no. 2 = N-(trichloromethylthio)-4-cyclohexene-1, 2-dicarboximide; no. 3 = same as no. 2, except more finely ground material; no. 4 = a commercial package including Captan (fungicide) and Parathion (insecticide).

5, 6, 7, 8, 9, 10, 11. Rohm & Haas Co. -- no. 5 = 2, 2'-thiobis(4-chlorophenol); no. 6 = benzyl dimethylamine mono-salt of bis(2-hydroxy-5-chlorophenyl)sulfide; no. 7 = tetramethyl thiuram trisulfide; no. 8 = ethylene bisthiuram trisulfide; no. 9 = bis(dimethylthiocarbamoyl)disulfide; no. 10 = disodium ethylenebis (dithiocarbamate) and ferric sulfate; no. 11 = disodium ethylenebis(dithiocarbamate) and manganese sulfate.

12, 13, 14, 15. Carbide and Carbon Chemical Co. -- no. 12 = 2-heptadecyl-2-imidazoline acetate; no. 13 = same as no. 12; no. 14 = 1, 2, 3-trithia-5, 8-diazacyclononane-4, 9-dithione; no. 15 = 1, 1'-trithiobis (N, N-dimethylthio-formamide).

16. Shell Chemical Corp. -- 2 heptadecyl 4, 4, 6-trimethyltetrahydropyrimidine.

24. -- O, o diethyl O, p-nitrophenyl thiophosphate.

25. General Chemical Co. -- (2, 3, 3a, 4, 5, 6, 7, 7a, 8, 8-decachloro-3a, 4, 7, 7a-tetrahydro-4, 7-methanoindene-1-one).

## RESULTS

Rohm and Haas Cr-305, an experimental fungicide, was sprayed on Elberta peaches during 1949 and imparted an off-flavor to the canned product. In 1950 this compound was sprayed on Redhaven peaches and later canned peaches were tested for off-flavor. The results of the flavor rating showed that the fungicide, CR-305, imparted a very abnormal or off-flavor to canned peaches. This flavor was difficult to describe. Several of the taste panel considered it an "inky" or chemical flavor.

In 1951 representative fruits of three peach varieties from 22 spray plots were taste tested. Fourteen fungicide combinations were compared. With the exception of one Elberta lot, sprayed with urea-sulfur combination, no marked difference was apparent in any of the flavor ratings. The flavor score of peaches sprayed with this combination was significantly different from the scores obtained with the other taste tests. This abnormal or off-flavor was probably due to fruit immaturity resulting from the use of the combination fungicide. At present the use of urea as a peach fungicide does not appear to be practical.

Captan-sprayed peaches were taste-tested during three seasons. The flavor of J. H. Hale peaches which received 8 spray applications of Captan in 1951 was not affected adversely. In 1952 Captan appeared to give an off-flavor to Southland canned peaches in the rated samples. When Captan-sprayed peaches were again checked, using the triangular taste tests, 9 out of 10 tasters selected or paired the Captan samples. In the same year, Captan also appeared to induce an off-flavor in canned peaches of the Burnett Elberta variety. During 1953, Captan was used in 9 different spray plots with no significant taste difference from those of the control samples. It seems possible that a different diluent was used with the 1952 Captan and may have been an important factor in the off-flavor reaction.

Rohm and Haas L. O. 737, appeared to give a slight off-flavor in one sample of J. H. Hale peaches in 1953. Another sample of J. H. Hale peaches sprayed with Manzate, also indicated a slight off-flavor. However, it seems doubtful if the scores were significant. Data are presented in Table 1.

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SOUTH CAROLINA AGRICULTURAL EXPERIMENT STATION, CLEMSON, SOUTH CAROLINA

# SOUTH CAROLINA SMALL GRAIN DISEASES -- 1954-55[1]

R. W. Earhart[2]

South Carolina farmers planted 1,177,000 acres[3] of small grains in the fall of 1954, which represented a 20 percent increase over the 1944-53 average. This increase is consistent with the present trend in the entire Southeastern United States where the added importance of livestock is being felt in the agricultural economy of the area. Increased small grain acreage was also predicated by 3 successive years of severe summer drought which emphasized the need for winter-grown animal feed.

In May and June of 1955, South Carolina farmers harvested 998,000 acres of small grains which produced 26,100,000 bushels of grain. This small grain crop was valued at $20,051,530 based on the July 15 market prices. It has been conservatively estimated that small grain diseases exacted a toll of approximately $4,000,000 from this year's crop, or an average loss because of diseases of $3.39 per harvested acre.

The most prevalent small grain diseases found in surveys were those which are not considered "killers", but which are always present to some degree and which cause insidious damage to crops every season. They were: oat leaf spot, wheat Septoria diseases, barley spot blotch, and rye leaf scorch. The effect of these diseases can be reduced by following recommended cultural practices, i. e., crop rotation, good seedbed preparation, adequate fertilization, planting cleaned and treated seed of recommended varieties, and sound grazing management.

A list of the small grain diseases in South Carolina is presented below in descending order of damage to 1954-55 crops. Methods for control, or reduction in damage, are suggested for each disease.

## Diseases of Oats:

Oats represent the largest small grain crop of the State, with 802,000 acres harvested in 1955. A total crop of 22,456,000 bushels of oats were produced, or 28.0 bushels per acre. The diseases attacking this crop were:

| Oat diseases | | Controlled by | | |
|---|---|---|---|---|
| | | Breeding | Seed treating | Crop rotation |
| Leaf Spot | *Helminthosporium avenae* | X | X | X |
| Culm Rot | *Helminthosporium sativum* | X | X | X |
| Victoria Blight | *Helminthosporium victoriae* | X | X | X |
| Septoria Black Stem | *Leptosphaeria avenaria* | X | | X |
| Mosaics | *Marmor terrestre* | X | | X |
| Smuts | *Ustilago avenae* & *U. kolleri* | X | X | |
| Crown Rust | *Puccinia coronata* | X | | |
| Stem Rust | *Puccinia graminis* | X | | |

1 Technical Contribution Number 245, South Carolina Agricultural Experiment Station.

2 Plant Pathologist.

3 All acreages, production, and market values from the South Carolina Crop Reporting Service.

Diseases of Wheat:

Wheat was harvested on 161,000 acres this season and produced a total of 3,059,000 bushels of grain, or 19.0 bushels per acre. The diseases attacking this crop were:

| Wheat diseases | | Controlled by | | |
|---|---|---|---|---|
| | | Breeding | Seed treating | Crop rotation |
| Septoria Diseases | Septoria nodorum & S. tritici | X | | X |
| Powdery Mildew | Erysiphe graminis | X | | |
| Loose Smut | Ustilago tritici | X | X | |
| Leaf Rust | Puccinia rubigo-vera | X | | |
| Mosaics | Marmor terrestre | X | | X |
| Stem Rust | Puccinia graminis | X | | |

Diseases of Barley:

South Carolina farmers harvested 20,000 acres of barley in 1955, which produced 420,000 bushels of grain or 21.0 bushels per acre. The diseases attacking this crop were:

| Barley diseases | | Controlled by | | |
|---|---|---|---|---|
| | | Breeding | Seed treating | Crop rotation |
| Loose Smut | Ustilago nuda | X | X | |
| Spot Blotch | Helminthosporium sativum | X | X | X |
| Powdery Mildew | Erysiphe graminis | X | | |
| Scald | Rhynchosporium secalis | X | X | X |
| Leaf Rust | Puccinia hordei | X | | |
| Stripe | Helminthosporium gramineum | X | X | X |

Diseases of Rye:

A total of 15,000 acres of rye, which produced 165,000 bushels of grain, or 11.0 bushels per acre, was harvested in South Carolina in 1955. Only three diseases were found damaging to rye:

| Rye diseases | | Controlled by | | |
|---|---|---|---|---|
| | | Breeding | Seed treating | Crop rotation |
| Leaf Scorch | Helminthosporium tritici-repentis | X | X | X |
| Leaf rust | Puccinia rubigo-vera | X | | |
| Stem Rust | Puccinia graminis | X | | |

## Summary

While the 1954-55 season could not be considered as a severe disease year, the farmers of South Carolina did sustain a loss of approximately $4,000,000.00 caused by diseases of small grain crops. Many of these diseases could be materially reduced by following the recommended cultural practices for these crops.

BOTANY DEPARTMENT, SOUTH CAROLINA AGRICULTURAL EXPERIMENT STATION

# PHYSIOLOGIC RACES OF CROWN RUST OF OATS IDENTIFIED IN 1954[1]

M. D. Simons[2]

## Summary

Newly numbered races of crown rust include races 276 through 279 and 287, discovered by Vallega and Cenoz; races 280 through 285, discovered by the author; race 286, discovered by Baker and Upadhyaya; and race 288, discovered by Lagos.

A total of 901 isolates distributed among 29 races, were identified from uredial material collected in the United States during 1954. Race 202 accounted for 30 percent of the total; race 203 for 21 percent; and race 258 for 14 percent. Races 264 and 276, which attack the varieties Landhafer, Santa Fe, Trispernia, and Bondvic, were each identified once.

A total of 61 isolates, distributed among 14 races, were identified from aecial material collected mainly from Rhamnus cathartica. Races 202 and 203 accounted for 25 and for 23 percent of the total, respectively. Only three out of 36 collections from R. lanceolata were parasitic on oats.

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Since the last compilation of previously unnumbered races of crown rust (Puccinia coronata Cda. var. avenae Fraser & Led.) was made (4) the discovery of a number of new races has been brought to the attention of the author. Vallega and Cenoz[3] have described five from Argentina (Table 1), which have been numbered 276, 277, 278, 279, and 287. All of these except race 279 attack four of the varieties (Landhafer, Santa Fe, Trispernia, and Bondvic) recognized as sources of resistance to races common in North America. The variety Victoria is resistant to all these races except race 279, and Saia is resistant to all of them. Race 279 is similar to the common North American race 213, except that Anthony is susceptible to 213 and resistant to 279.

In the course of the author's identification of collections made in the United States during 1954, six new races were observed (Table 1). These were numbered 280 through 285. None of them attacked any of the varieties representing sources of resistance to races common in North America at present, and were distinguished from previously known races, and from each other, mainly by their lack of aggressiveness on varieties susceptible to many of the common races.

Race 286, from Australia, has been described by Baker and Upadhyaya (1). It attacks the common sources of resistance being used in North America.

Additional publications concerned with the identification of races of crown rust that have come to the attention of the author since such information was last summarized (4) include one by Lagos (2), one by Wahl and Schreiter (6) and one by Wahl (5). Lagos described 12 races identified from material collected in Brazil and Argentina. Seven of these were races that have been previously described by other investigators. Four (races 265, 266, 267, and 269) were first discovered by Lagos, and were assigned numbers earlier (4). It should be noted that the original description of race 266 indicated that Bondvic was moderately susceptible, while the paper referred to above indicates that the reaction of Bondvic is intermediate. In view of the small difference involved, and in order to avoid confusion, it is felt that no change should be made in the numbering. One of the races identified by Lagos had not been numbered previously. It attacks Anthony, Appler, Ukraine, Bondvic, and Saia; the remaining differential varieties are resistant. It has been assigned number 288 (Table 1).

Wahl and Schreiter (6) and Wahl (5) have published data on the extremely aggressive races of crown rust occurring in Israel. One of these, race 264, attacks all the differential varieties except Saia. This race, which was at one time erroneously assigned the number 276 by this writer, is apparently quite similar to the race 276 described by Vallega and Cenoz. Because of

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[1]Cooperative investigation between the Field Crops Research Branch, Agricultural Research Service, U. S. Department of Agriculture, and the Iowa Agricultural Experiment Station. Journal Paper No. J-2827 of the Iowa Agricultural Experiment Station, Ames, Iowa; Project No. 1176. The writer wishes to acknowledge his indebtedness to the investigators in other countries who have generously made their data available, and to those in the United States who have supplied crown rust collections for identification.

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Table 1. Reaction[a] of the new set of 10 differential varieties of oats in the seedling stage to 13 races of crown rust.

| Race[b] | Differential variety and variety number | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Anthony | Victoria | Appler | Bond | Landhafer | Santa Fe | Ukraine | Trispernia | Bondvic | Saia |
| | 101 | 102 | 103 | 104 | 105 | 106 | 107 | 108 | 109 | 110 |
| | Average reaction of differential varieties | | | | | | | | | |
| 276 | S | R | S | S | S | S | S | S | S | R |
| 277 | S | R | S | R | S | S | R | S | S | R |
| 278 | R | R | S | R | S | S | S | S | S | R |
| 279 | R | S | S | S | R | R | R | R | R | R |
| 280 | S | R | R | S | R | R | R | R | R | S |
| 281 | S | R | R | S | R | R | S | R | R | S |
| 282 | R | S | S | R | R | R | R | R | R | R |
| 283 | R | S | S | R | R | R | S | R | R | R |
| 284 | S | R | R | S | R | R | S | R | R | R |
| 285 | S | S | R | S | R | R | R | R | R | R |
| 286 | S | R | S | R | S | S | S | S | S | R |
| 287 | R | R | S | R | S | S | R | S | S | R |
| 288 | S | R | S | R | R | R | S | R | S | S |

[a] "R" indicates that the variety is resistant (infection types I, 0, 1, and 2) to the race, and "S" (infection types 3 and 4) indicates susceptibility.

[b] Races were first identified as follows: races 276 through 279 by Vallega and Cenoz (footnote 2); races 280 through 285 by the author; race 286 by Baker and Upadhyaya (1); race 287 by Vallega and Cenoz (footnote 2); race 288 by Lagos (2).

this incorrect designation, the Israeli investigators referred to their race 264 as race 276. The relationship of these races is discussed in more detail below.

A total of 704 collections of crown rust on oats made in 28 states in 1954 were received at Ames, Iowa. Not all of these, of course, contained viable spores. The viable collections were increased on a susceptible variety, and the spores obtained were used to inoculate the differential varieties. In most cases where inspection of the differentials indicated that race mixtures were involved, single pustule isolates were made from the differential varieties. These were then increased, identified, and counted as isolates. No collection, however, was credited with contributing more than one isolate of a given race, even though several were identified. On this basis, 901 isolates were obtained (Table 2). These isolates were distributed among 29 races, of which race 202, accounting for 30 percent of the total, was the most common. This represents a considerable decrease in prevalence of race 202 as compared with the comparable figure of 45 percent in 1953. Race 202 attacks the varieties Anthony, Appler, and Bond. The remaining differentials, Victoria, Landhafer, Santa Fe, Ukraine, Trispernia, Bondvic, and Saia, are resistant. Race 203, making up 21 percent of the total, was second in prevalence, and was some-

what more common than in 1953. It differs from race 202 only by its ability to attack Ukraine.

Race 258 was third in prevalence, showing a more striking increase than any other race. It constituted 14 percent of the total as compared with 3 percent in 1953. The geographical distribution of this race was also interesting, being heavily concentrated in the southeastern states of Alabama, Florida, and Georgia. In these states it ranged from about one-third to one-half of all the isolates identified. By contrast, it was identified only once among the 211 isolates obtained from material collected in Iowa. Victoria, and commercial varieties possessing the Victoria type of crown rust resistance, are moderately, but not fully susceptible to most isolates of race 258, while Bond and its derivatives are resistant or moderately resistant. Two other common races attacking Victoria, 216 and 213, made up 9 and 8 percent, respectively, of the total number of isolates. The reaction of Victoria to race 213 is similar to its reaction to race 258. Race 213 also often induces a certain amount of necrosis, along with susceptible-type uredia, in Bond, so that it is sometimes difficult to distinguish the two races. The isolates comprising race 216 may be divided into two rather clear-cut sub-races, one of which induces a fully susceptible reaction in Victoria. The other induces a moderately susceptible reaction, in this way resembling races 213 and 258.

No other single race accounted for more than 3 percent of the total number of isolates. Two races, 264 and 276, reported from the United States for the first time, deserve special mention. A culture of race 264 was isolated from a collection made in Elmore County, Alabama, by J. A. Lyle on May 6, 1954. The fraction of race 264 contained in this collection was apparently very small, as there was no evidence of it on the differential varieties inoculated with a bulk increase of the collection. It first appeared as a few contaminating uredia in a single pustule isolate of the original collection. An apparently pure culture was obtained and identified from these uredia. These circumstances suggest the possibility that the culture did not originate in the collection from Alabama, but simply came in as a contaminant from some other source. According to Simons (4) race 264 was first described by Wahl in Israel. Saia is highly resistant; Victoria is moderately to fully susceptible, while the remaining differential varieties are fully susceptible.

A culture of race 276 was isolated from a collection made by the author near Stanhope, Iowa, on July 8, 1953. This was a collection of crown rust from Agropyron repens growing near volunteer plants of Rhamnus cathartica, and separated by only a few feet from a field of oats. The collection was increased on a susceptible variety of oats, and was shown to consist of a mixture of races, one of which was race 276. The culture of race 276 would not infect A. repens, indicating possibly that it had originated as spores simply blown from the nearby oats to the leaves of the A. repens. Race 276 was first identified by Vallega and Cenoz as described above.

Race 263, collected in Manitoba in 1953 (3), was not seen in 1954. The author's North American culture of race 263 differs sharply from available cultures of races 264 and 276 by the reaction of Ukraine, which is highly resistant to race 263, but fully susceptible to the other two. Victoria is regarded as moderately resistant to races 263 and 276. In the earlier stages of development and under certain environmental conditions, however, the reaction of Victoria may be intermediate or even susceptible. The susceptible reaction of Victoria to race 264, on the other hand, may be altered with age or under certain other conditions to an intermediate or even moderately resistant type. Consequently, it appears that the North American cultures of races 264 and 276 are very much alike, and future work may indicate that they should not be separated at the racial level.

Of the six new North American races described above, race 280 occurred five times; 281, four times; 282, twice; 283, three times; 284, four times; and 285, once. Race 279 was described in South America shortly before it was discovered in the United States. It is apparently quite similar to race 213 and was identified five times.

Nineteen races, representing about 80 percent of all isolates identified, attacked Bond. In 1953 races attacking Bond represented about 90 percent of all isolates. Most of this difference is accounted for by the increased prevalence of race 258 in 1954. The 11 races attacking Victoria represented 34 percent of the total isolates, an increase in prevalence of Victoria races of about 10 percent. Again, this was mainly due to the increased prevalence of race 258.

A fairly large number of aecial collections were received in the spring of 1954, but many contained no viable spores, and others were lost due to unusually hot weather at the time they were being increased. A total of 61 uredial isolates, originating mainly on Rhamnus cathartica, from six states were identified (Table 3). These isolates were distributed among 14 races, with races 202 and 203 being most common. Races 237 and 231, neither of which parasitize either Bond or Victoria, were next in importance. Two races, 236 and 240, that did not occur in the material collected from oats were identified. Race 240 is noteworthy for its lack of aggressive-

Table 2. Physiologic races of Puccinia coronata avenae isolated from oats in 1954.

| Area and state | Prevalence and distribution of physiologic races: | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 201 | 202 | 203 | 205 | 210 | 211 | 212 | 213 | 214 | 216 | 226 | 227 | 231 | 232 | 235 | 237 | 241 | 258 |
| NORTH CENTRAL | | | | | | | | | | | | | | | | | | |
| Illinois | | 7 | 2 | | | | | | | 1 | | | | | | | | |
| Iowa | 10 | 67 | 72 | 8 | | 4 | 1 | 6 | | 23 | 1 | 1 | | 1 | | | 10 | 1 |
| Kansas | | 2 | 9 | | | | | | | 1 | | | | | | | | |
| Michigan | | 3 | 5 | 1 | | | | 1 | | 3 | | | | 1 | | | | |
| Minnesota | | 7 | 6 | | | | | 2 | | 2 | 1 | 1 | | | | | | |
| Missouri | | 4 | 1 | | | | | | | | | | | | | 2 | 1 | 3 |
| Nebraska | | 1 | | | | | | | | | | | | | | | | |
| North Dakota | | 32 | 14 | 2 | | | | 8 | | 4 | | | | | | 1 | 1 | 2 |
| Ohio | | 2 | | | | | | | | | | | | | | | | |
| South Dakota | | 2 | 6 | 1 | | | | | | 3 | | | | | | | 1 | |
| Wisconsin | | 21 | 15 | 1 | | | | 3 | 1 | 3 | | | | | | | | 1 |
| EASTERN | | | | | | | | | | | | | | | | | | |
| Maine | | 1 | 1 | | 1 | | 2 | 1 | | 1 | | | 1 | 2 | | | | |
| New York | | 1 | 1 | 2 | | | 1 | | | 1 | | | | | | | | |
| SOUTHERN | | | | | | | | | | | | | | | | | | |
| Alabama | 2 | 25 | 15 | 8 | | 2 | | 17 | 1 | 14 | 1 | | | 1 | 1 | 9 | 2 | 62 |
| Arkansas | | 2 | 1 | | | | | 1 | | | | | | 1 | | | | 2 |
| Florida | 4 | 24 | 11 | | | | | 14 | | 9 | 2 | | | | | 2 | | 29 |
| Georgia | 1 | 4 | 1 | | | | | 4 | | 1 | | | | | | 1 | | 12 |
| Louisiana | | 5 | | | | | | 2 | | | | | | | | 4 | | 3 |
| Mississippi | | 6 | 11 | 1 | | 5 | | | | 1 | | | | | | 1 | | |
| North Carolina | 1 | 7 | 4 | | | | | 3 | | 2 | 1 | | | | | | 1 | 1 |
| South Carolina | 1 | 13 | 6 | | | 1 | | 2 | | 2 | | | | | | 1 | | 3 |
| Tennessee | | 1 | | | | | | | | | | | | | | | | |
| Texas | 4 | 22 | 3 | | | | 1 | 3 | | 4 | | | | | | 1 | | |
| Virginia | 1 | 5 | 1 | | | | | | | 2 | | | | | | 1 | | 2 |
| West Virginia | | 1 | | | | | | 2 | | | | | | | | | | 1 |
| WESTERN | | | | | | | | | | | | | | | | | | |
| California | 1 | 1 | | | | | | | | | | | | | | | | |
| Montana | | 6 | 1 | | | | | | | | | | | | | | | |
| Oregon | | | | | | | | | | | | | | | | | 1 | |
| Total | 25 | 272 | 186 | 24 | 1 | 12 | 5 | 69 | 2 | 77 | 6 | 2 | 1 | 6 | 1 | 23 | 17 | 122 |
| Percent | 2.8 | 30.2 | 20.6 | 2.7 | 0.1 | 1.3 | 0.6 | 7.7 | 0.2 | 8.5 | 0.7 | 0.2 | 0.1 | 0.7 | 0.1 | 2.6 | 1.9 | 13.5 |
| States | 9 | 27 | 21 | 8 | 1 | 4 | 4 | 15 | 2 | 18 | 5 | 2 | 1 | 5 | 1 | 10 | 7 | 13 |
| Areas | 3 | 4 | 4 | 3 | 1 | 2 | 3 | 3 | 2 | 3 | 2 | 1 | 1 | 3 | 1 | 2 | 3 | 2 |

Table 2. (Continued)

| Area and state | Prevalence and distribution of physiologic races: 259 | 264 | 274 | 276 | 279 | 280 | 281 | 282 | 283 | 284 | 285 | Total Isolates | Total Races |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NORTH CENTRAL | | | | | | | | | | | | | |
| Illinois | | | | | | | | | | | | 10 | 3 |
| Iowa | | | 1 | 1 | 1 | 2 | | | | 1 | | 211 | 18 |
| Kansas | | | | | | | | | | | | 12 | 3 |
| Michigan | | | | | | | | | | 1 | | 15 | 7 |
| Minnesota | | | | | | | | | | | | 19 | 6 |
| Missouri | 1 | | | | | | | | | | | 12 | 6 |
| Nebraska | | | | | | | | | | | | 1 | 1 |
| North Dakota | | | | | | | | | | | | 64 | 8 |
| Ohio | | | | | | | | | | | | 2 | 1 |
| South Dakota | | | | | | | | | | | | 13 | 5 |
| Wisconsin | | | | | | | | | | | | 45 | 7 |
| EASTERN | | | | | | | | | | | | | |
| Maine | | | | | | | 2 | | | 2 | 1 | 15 | 11 |
| New York | | | | | | 1 | | | | | | 7 | 6 |
| SOUTHERN | | | | | | | | | | | | | |
| Alabama | 10 | 1 | | | 4 | | 2 | 1 | 2 | | | 180 | 20 |
| Arkansas | | | | | | | | | | | | 7 | 5 |
| Florida | 7 | | | | | | | | | | | 102 | 9 |
| Georgia | 1 | | | | | | | | | | | 25 | 8 |
| Louisiana | | | | | | | | | | | | 14 | 4 |
| Mississippi | | | | | | 1 | | | | | | 26 | 7 |
| North Carolina | | | | | | | | | | | | 20 | 8 |
| South Carolina | | | | | | | | | | | | 29 | 8 |
| Tennessee | | | | | | | | | | | | 1 | 1 |
| Texas | | | 1 | | | | | | | | | 39 | 8 |
| Virginia | | | 3 | | | 1 | | 1 | 1 | | | 18 | 10 |
| West Virginia | | | | | | | | | | | | 4 | 3 |
| WESTERN | | | | | | | | | | | | | |
| California | | | | | | | | | | | | 2 | 2 |
| Montana | | | | | | | | | | | | 7 | 2 |
| Oregon | | | | | | | | | | | | 1 | 1 |
| Total | 19 | 1 | 5 | 1 | 5 | 5 | 4 | 2 | 3 | 4 | 1 | 901 | 29 |
| Percent | 2.1 | 0.1 | 0.6 | 0.1 | 0.6 | 0.6 | 0.4 | 0.2 | 0.3 | 0.4 | 0.1 | | |
| States | 4 | 1 | 3 | 1 | 2 | 4 | 2 | 2 | 2 | 3 | 1 | 28 | |
| Areas | 2 | 1 | 2 | 1 | 2 | 3 | 2 | 1 | 1 | 2 | 1 | 4 | |

Table 3. Physiologic races of Puccinia coronata avenae isolated from Rhamnus spp. in 1954.

| State | Prevalence and distribution of physiologic races: | | | | | | | | | | | | | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 201 | 202 | 203 | 205 | 212 | 216 | 226 | 231 | 235 | 236 | 237 | 240 | 241 | 284 | Isolates | Races |
| Illinois | | | 1 | | | | | | | | | | | | 1 | 1 |
| Iowa | 1 | 12 | 10 | 2 | 2 | 1 | 3 | 4 | 1 | 1 | 8 | 2 | 1 | 1 | 49 | 14 |
| Minnesota | | 1 | | | | | | | | | 1 | 1 | | | 3 | 3 |
| Nebraska | | 1 | | | | | | | | | | | | | 1 | 1 |
| South Dakota | | 1 | 2 | | | | | 1 | | | | 1 | | 1 | 6 | 5 |
| Wisconsin | | | 1 | | | | | | | | | | | | 1 | 1 |
| Total | 1 | 15 | 14 | 2 | 2 | 1 | 3 | 5 | 1 | 1 | 9 | 4 | 1 | 2 | 61 | 14 |
| Percent | 1.6 | 24.6 | 23.0 | 3.3 | 3.3 | 1.6 | 4.9 | 8.2 | 1.6 | 1.6 | 14.8 | 6.5 | 1.6 | 3.3 | | |

ness, all the differentials except Anthony being resistant.

Only three out of 36 collections made from R. lanceolata in southern Iowa were pathogenic on oats. Most of the remainder induced only flecking in the susceptible oat variety Markton, although several induced flecking in combination with a few very small uredia. Attempts to build up cultures from these small uredia were unsuccessful.

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FIELD CROPS RESEARCH BRANCH, AGRICULTURAL RESEARCH SERVICE, U. S. DEPARTMENT OF AGRICULTURE, AND IOWA AGRICULTURAL EXPERIMENT STATION, AMES, IOWA

# AN EXAMINATION OF THE PRESENT STATUS AND PROPOSED MODIFICATIONS OF THE ANNUAL CROWN RUST RACE SURVEY IN THE UNITED STATES[1]

M. D. Simons[2]

SUMMARY

The two principal objectives of the crown rust race identification program in the United States are to furnish data on the year to year prevalence of the various races, and to detect new and potentially dangerous forms as soon as possible after they appear. Perhaps less important, but worthy of consideration, are such factors as the relative prevalence of specific races over a long period of years, and the comparison of races occurring in North America with those occurring on other continents. When all these objectives are considered, it is obvious that the present methods used in the annual crown rust survey are not so efficient as they could be. In order to provide less biased data on the relative prevalence of the different races, it is proposed that only single isolates from collections of crown rust made on completely susceptible varieties of oats such as Markton and Richland be used. These isolates would be identified on the new standard set of ten differential varieties. In order to detect more efficiently new and potentially dangerous forms of crown rust it is proposed that a nonpermanent set of differential varieties be established. This set would contain only selections resistant to common North American races that are of use or of potential use as sources of resistance, and would be used for testing all crown rust collections received during a given year. Anyone interested in breeding for resistance to crown rust could submit new selections for possible inclusion in this set.

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A sizable body of literature has been devoted to the consideration of ways and means by which the identification of races of the various cereal rusts could be effected, modified or improved. Much of this literature has been reviewed by Chester (1) and Silva (3), and more recently by Freitas (2). The purposes of this paper are to re-examine briefly the objectives of the annual crown rust race survey carried out in the United States, to determine the shortcomings of the present system in light of these objectives, and finally to suggest modifications that would result in more nearly attaining these objectives.

The discovery of physiologic specialization of a cereal rust fungus for pathogenicity at the varietal level of the host by Stakman and Piemeisel (6) was, in terms of far reaching effects, one of the most significant contributions ever made to the science of phytopathology. In the broad sense, this information has greatly aided the intelligent, overall evaluation of the whole rust problem. More specifically, it has been useful in such diverse ways as assessing the role of alternate hosts of certain rusts in the origin of new races, and pointing out the existence of potentially dangerous sources of inoculum in different geographic areas. By far the most important use, however, has been in its practical application in numerous cereal breeding programs, where it has placed breeding for rust resistance on a much sounder basis than would have been possible otherwise.

## Physiologic Specialization Versus Racial Identity

The concept of racial identity has been closely tied to this type of physiologic specialization almost since its discovery. These two ideas, in fact, have not always been clearly differentiated in the literature. It is important to remember that physiologic specialization for pathogenicity is a natural phenomenon exhibited by the cereal rust fungi. The concept of racial identity, on the other hand, simply constitutes an artificial means of grouping the almost innumerable physiologic, or perhaps more accurately, pathologic, forms represented by the individual clones comprising the populations of most of the common cereal rusts.

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## Permanent Differentials Versus a Nonpermanent System

A race, by definition for purposes of this discussion, is one or more clones of rust that induce specified reactions in a certain specified set of "differential" varieties. Without individually testing them, there is no way of knowing how varieties carrying different genes for rust reaction will react to clones defined by their behavior on such a specified set of varieties. In other words, individual clones of the same race may differ, but the difference might not be apparent unless they are tested on varieties outside the specified set. Obviously, the choice of the varieties that go into this set is of the greatest importance. If the varieties chosen represent the common genetic sources of resistance that are available to, and are being used by plant breeders, the information gained by identification of rust collections on them will benefit plant breeders. Information gained by identification of rust collections on varieties that are not being grown commercially or are not of use as sources of resistance has very little practical value, although it may be of considerable historical or purely taxonomic interest.

Unfortunately, breeding for resistance to crown rust, as well as other cereal rusts, represents a more or less constantly changing problem. Races arise from time to time that are able to attack varieties of oats that the previously known races could not attack. To combat this situation plant pathologists and breeders search for new selections of oats resistant to the new races. As these new, resistant strains are found and made use of, the older, no longer useful varieties may be discarded. It has been suggested (4) that the logical thing would be to eliminate these old varieties from the set of differential varieties. There are certain advantages, however, in maintaining the same set of differential varieties over the years. The use of a uniform set, for example, may facilitate international cooperation, although the value of such cooperative use is sometimes open to question. In the case of crown rust there was an instance in which a race common in the United States (race 45) was also shown to exist in South America (7). The differential varieties upon which it was defined, however, did not include certain newer sources of resistance that were being used extensively in oat breeding programs. The significant discovery that South American isolates of race 45 could attack most of these newer sources of resistance, which were resistant to all known North American isolates of this race, was made in spite of, rather than because of, the cooperative use of a uniform set of differential varieties. In this case, at least, it is apparent that a uniform, unchanging set could easily have done more harm than good.

Another advantage of using a uniform set of differential varieties is that a comparison of the relative prevalence of various races over the years is made possible. The practical value of such comparisons is subject to the criticism just mentioned, that is, cultures of races identified at present might well be shown to differ from cultures of the same races identified in past years if they all could be tested on varieties outside the standard set. Much the same sort of thing applies when we consider the value of a uniform set of varieties for historical or taxonomic purposes. One distinct advantage of a uniform set is that it results in a unified numbering system for the races identified. Thus it is relatively simple for the investigator who is identifying collections of rust to report his results in terms that can be readily understood. The question of course, is whether such information, even though easily understood, is of maximum value to all concerned.

## Discovery of New Forms Versus Prevalence of Known Races

Another phase of the crown rust survey that is possibly just as important as the discovery and cataloging of new forms is the collecting of data on the relative prevalence of races that are already known to exist. By comparing the relative prevalence of different races from year to year it is possible to estimate which are the most common, which are increasing, and which are decreasing, and therefore, to which the most attention should be given. Needless to say, such prevalence data should be as unbiased as possible. That is, the prevalence of a given race as shown by race survey data should correspond as closely as possible to the actual relative prevalence of that race in the field. This objective is sometimes at cross-purposes with the other major objective of the annual survey, namely that of identifying and reporting new, potentially dangerous forms of crown rust, as soon as possible after they first appear. Such new forms of rust are most likely to be first seen and collected on varieties regarded as resistant to the previously known races. As individual investigators are, quite properly, concerned about the appearance of new forms, a large proportion of the collections of crown rust that are identified each year are made originally on more or less resistant varieties. At present all crown rust collections received during the year are individually increased on a susceptible variety and iden-

tified on the standard set of ten differentials. Many, of course, are mixtures of two or more races. Where the components of these mixtures can not be identified, single pustule isolates are made, increased, and identified. For the computation of prevalence data each distinct race identified among the isolates from a given collection is counted as one isolate of that race. However, a given collection is never credited with contributing more than one isolate of any one race. Although an approximation can be made (5), it is difficult to make any sort of accurate allowance for the relative amounts of the different races comprising a mixture of this type. There is also a good possibility of completely missing some of the rare components of such mixtures, the less aggressive races being particularly liable to being slighted. Obviously, prevalence data obtained in this manner constitute a biased estimate of the actual relative prevalence of the races as they occur in the field.

## Less Biased Prevalence Data

In order to obtain less biased and more accurate prevalence data, it is proposed that only crown rust collections from completely susceptible varieties such as Markton and Richland be used. Such collections should comprise a representative, random sample of the crown rust population, as these varieties have no known "screening" effect. Both varieties occur in the Uniform Oat Rust Nursery. In an average year crown rust collections are received from about 30 uniform rust nurseries at various locations throughout the United States. Collections made from these two varieties and possibly other susceptible varieties would be increased directly on the variety Markton in the greenhouse. About ten single pustule cultures from each collection would then be isolated, increased, and identified on the new standard set of ten differential varieties. The several hundred cultures so obtained and identified would furnish a much less biased estimate of the actual prevalence of the races occurring in the field than the system being used at present. Since a standard and unchanging set of differential varieties would be used, this plan would also have all the advantages of such a set that have been mentioned above.

## Detection of New, Aggressive Forms

This method, however, is not well suited to the task of detecting new or rare, potentially dangerous physiologic forms, nor does it give any information on the reaction of newly discovered sources of resistance to physiologic forms occurring at the present time. In order to overcome these objections it is proposed that a special set of "differentials" be set up. This set would change from year to year, possibly, or whenever a change was indicated by the discovery of new sources of resistance or by changes in the rust population. The selections included would have to possess certain characteristics. First, they must be resistant to the common North American races of crown rust. Second, there must be some evidence that the basis of their resistance differs genetically from that of other available sources of resistance. Four (Landhafer, Santa Fe, Trispernia, and Bondvic) varieties of the present standard set of ten differentials would meet these requirements. The remaining varieties of the new standard set would not be included, as they would provide no information on the occurrence of new, dangerous forms of crown rust, and their inclusion would result in a correspondingly greater expenditure of labor and greenhouse facilities. Anyone interested in breeding for crown rust resistance could propose the addition of new sources of resistance to this set at any time, provided the selection in question met the requirements outlined above.

All collections received during the year, including those from both resistant and susceptible varieties, would be increased, individually, on plants of a susceptible variety, and used to inoculate this special set of resistant selections. This would, in effect, constitute the testing of these resistant selections for reaction to the largest possible sample of the available physiologic forms comprising the crown rust population. All of the selections would, of course, be resistant to the big majority of the collections since a selection showing susceptibility to any appreciable percentage would be dropped from the special set. Relatively little time and labor would be involved in determining the racial identity of the few isolates that might be found to attack one or more of the selections of the special set. For purposes of designation, these isolates could then be referred to as specific "biotypes" (5) of their respective races.

The requirements outlined above make no allowance for one situation that could in theory, at least, arise. A given selection could be of potential value as a source of resistance to certain relatively rare forms that attack the common sources of resistance. This selection, however, might be susceptible to the common races of crown rust. In such a case the selection would not meet the requirements outlined above, and, therefore, would not be subjected to annual testing

with a large number of collections of crown rust. The problem would be to determine whether or not new forms were arising that were capable of attacking the other sources of resistance, that is, sources of resistance to the common races, that could also attack the selection that was resistant to the rare, but not to the common forms. Since, in the system outlined above, isolates attacking the common sources of resistance would be relatively rare, the few that did attack these sources of resistance could be used for individually testing the selection in question.

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# SMUT RESISTANCE OF SOME SOUTHERN OAT VARIETIES[1]

Darrell D. Morey[2]

## Summary

In tests at the Coastal Plain Experiment Station, Tifton, Georgia, Seminole, Coker 53-29, and Delair oats showed high resistance to two collections of oat smuts. C.I. Nos. 6571, 6717, and 6744 oats from the Texas-U.S.D.A. cooperative breeding experiments also showed a high type of resistance. C.I. 6671 from Iowa, C.I. 6909 and C.I. 7098 from Minnesota and two oat selections from Canada were found to have combined resistance to rusts and smuts.

Many oat varieties and selections derived from the cross Lee x Victoria were susceptible to smuts. Atlantic, Fultex, DeSoto, Stanton 1, Letoria, Alamo, Camellia, Southland and Floriland were susceptible.

Victorgrain 48-93, Fulgrain, Arlington, and most Red Rustproof types were intermediate in susceptibility to the smuts used in this study.

## Introduction

In breeding oats at the Coastal Plain Experiment Station, chief attention has been given to the development of oats resistance to crown and stem rusts. However, reaction to loose smut, Ustilago avenae (Pers.) Rostr. and covered smut, U. kolleri Wille, has been tested in several seasons.

It has been customary to grow uniform nurseries without seed treatment so that observations could be made on seed-borne diseases. Some oat varieties were never observed to be infected with smut, while others became heavily infected after a few seasons. This was also observed under farm conditions. Varieties reported to be resistant occasionally were found to be rather heavily infected with smut.

There was also reason to believe that breeding for resistance to the smuts could be accomplished in the same program where major emphasis was given to rust resistance. By testing parents and early generation material for resistance to smuts as well as to virulent rust races, it was believed possible to fix resistance to all three diseases in one or more adapted strains.

In 1946 Hansing et al. (1) reported that races of loose smut in Kansas attacked Fulghum, Kanota, Fultex and many selections from crosses of Victoria x Richland and Lee x Victoria. In 1942, Reed and Stanton (2) reported a race of loose smut collected from Fulghum which attacked Lee and Victoria and many derivatives from the cross of these two varieties. Preliminary tests indicated that varieties with similar breeding were being attacked by smuts in the Southern States.

The purpose of this investigation was to learn more about the resistance of Southern oat varieties and breeding materials to two different collections of smuts.

## Materials and Methods

Oat varieties in the Uniform Fall-Sown test and the Florida-Gulf Coast test were inoculated artificially with smuts before fall seeding in 1953 and 1954, at the Coastal Plain Experiment Station, Tifton, Georgia. Other special breeding lines also were tested. Two collections of Southeastern oat smuts were used. One of these, made up principally of loose smut and termed "Tifton composite," was collected from experimental plots and fields in the vicinity of Tifton, Georgia. The second collection, furnished by Coker's Pedigreed Seed Company, Hartsville, South Carolina, was made up chiefly of three races of loose smut. One of these races was collected from Fulgrain Strain 3, C.I. 3253, another from Fulghum, and the third from Victoria derivatives such as Arlington, Stanton 1 and Letoria.

Thirty seeds of each entry were dehulled by hand for the 1954 tests, and 40 seeds for the 1955 tests. Dry chlamydospores were added in equal amounts to each envelope of seed a few

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**Table 1. Smut infection in oat varieties artificially inoculated with two collections in two years at Tifton, Georgia.**

| Variety or Selection | C.I. or Sel. No. | 1954 Tifton Comp. Tests | 1954 Tifton Comp. Plants Smutted | 1954 Tifton Comp. Plants Not Smutted | 1954 Coker Coll. Plants Smutted | 1954 Coker Coll. Plants Not Smutted | 1955 Tifton Comp. Tests | 1955 Tifton Comp. Plants Smutted | 1955 Tifton Comp. Plants Not Smutted | 1955 Coker Coll. Plants Smutted | 1955 Coker Coll. Plants Not Smutted | Percent Smutted Plants |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Seminole | 5924 | 3 | 0 | 38 | 0 | 52 | 3 | 0 | 40 | 0 | 44 | 0.0 |
| (Arlington x Delair) x Trisp:C-53-29 | 6987 | 2 | 0 | 34 | 0 | 27 | 3 | 0 | 61 | 0 | 71 | 0.0 |
| S. Fe-Cl. x Sac-H.J. | 6671 | | | | | | 1 | 0 | 14 | 0 | 17 | 0.0 |
| South.-Land. x Minn. 19-11 | 7011 | | | | | | 1 | 0 | 18 | 0 | 14 | 0.0 |
| (Roxton x V-H-B-(Ajax-V-H-B) | 3928-5-4 | | | | | | 2 | 0 | 27 | 0 | 15 | 0.0 |
| (Roxton x V-H-B-(Ajax-V-H-B) | 3928-5-8 | | | | | | 2 | 0 | 22 | 0 | 17 | 0.0 |
| Trispernia x $Cl^2$-S.Fe | 6978 | | | | | | 1 | 0 | 17 | 0 | 17 | 0.0 |
| Garry | 6662 | | | | | | 2 | 0 | 25 | 0 | 14 | 0.0 |
| (Landh x (Mindo x H-J) x And. | 6909 | | | | | | 2 | 0 | 34 | 0 | 19 | 0.0 |
| " " " " | 7098 | | | | | | 1 | 0 | 15 | - | - | 0.0 |
| Landh x (Mindo x Haj.-Joan) | 6914 | 1 | 0 | 3 | 0 | 3 | 1 | 0 | 3 | 0 | 3 | 0.0 |
| R.N.P. - Victoria x Norton | 5372 | 1 | 0 | 17 | 0 | 14 | | | | | | 0.0 |
| Fla. 167 x Landhafer | 5913 | 1 | 0 | 4 | 0 | 3 | | | | | | 0.0 |
| James (Hull-less) | 5015 | | | | | | 1 | - | - | 0 | 20 | 0.0 |
| H.J.-4383 x 4189 - Landhafer | 6574 | 1 | 0 | 5 | 0 | 4 | | | | | | 0.0 |
| Lee-Vic. x Fulwin | 6717 | 1 | 0 | 12 | 0 | 14 | 2 | 2 | 15 | 1 | 27 | 4.2 |
| South-Land. x Minn. 19-11 | AB205 | 1 | 1 | 14 | 0 | 7 | | | | | | 4.5 |
| Delair | 4653 | 1 | 0 | 15 | 0 | 14 | 2 | 3 | 36 | 2 | 32 | 4.9 |
| (Vic. x H.-B) x Fulghum-Vic. | 6744 | 1 | 0 | 10 | 0 | 14 | 1 | 1 | 12 | 2 | 17 | 5.4 |
| Trispernia x $Cl^2$-S. Fe | 6582 | 1 | 1 | 7 | 0 | 9 | | | | | | 5.9 |
| 4024 x 3927 - Wintok x Land. | 8M | | | | | | 2 | 2 | 32 | 2 | 25 | 6.5 |
| Minn. 48-8 x Southland | 7015 | | | | | | 1 | 0 | 2 | 1 | 12 | 6.6 |
| Bronco | 6571 | 1 | 0 | 13 | 1 | 8 | 2 | 2 | 16 | 1 | 17 | 6.9 |
| Fulgrain | 6585 | 1 | 0 | 17 | 0 | 17 | 2 | 7 | 25 | 0 | 30 | 7.3 |
| Santa Fe x Stanton-Fulgrain | 6907 | 2 | 1 | 19 | 2 | 19 | | | | | | 7.3 |
| Fla. 167 x Land x Southland | 6757 | 1 | 0 | 10 | 0 | 9 | 1 | 1 | 12 | 3 | 10 | 8.9 |
| CI 4019 x Fulghum-Vic. | 5873 | 1 | 2 | 7 | 0 | 11 | | | | | | 10.0 |
| Terruf (Red Rustproof Type) | 3479 | 1 | 0 | 18 | 4 | 9 | | | | | | 12.9 |
| Sac. H.J. x Fla. 167 | 6599 | 1 | 1 | 6 | 0 | 0 | | | | | | 14.3 |
| Mustang | 4660 | 1 | 6 | 2 | 0 | 10 | 2 | 4 | 9 | 0 | 29 | 16.6 |
| Minn. 48-8 x Southland | 7014 | | | | | | 1 | 6 | 10 | 2 | 22 | 20.0 |
| Arlington | 4657 | 1 | 0 | 17 | 2 | 10 | 2 | 10 | 34 | 5 | 18 | 24.0 |
| Coker's BL-47-67 | | | | | | | 1 | 7 | 22 | | | 24.1 |
| Nortex x Trelle Dwarf | 6729 | 1 | 0 | 11 | 0 | 12 | 2 | 5 | 25 | 18 | 22 | 24.7 |
| Floriland x Southland Q-5332 | | 1 | 1 | 6 | 2 | 3 | | | | | | 25.0 |
| Letoria x $Cl^2$-S.Fe | 6921 | 1 | 0 | 1 | 3 | 8 | | | | | | 25.0 |
| (Atl. x $Cl^2$-S.Fe) x CI 4024 | 6923 | 1 | 4 | 8 | 1 | 5 | | | | | | 27.8 |
| Appler | 1815 | 2 | 1 | 27 | 1 | 24 | 5 | 8 | 64 | 49 | 31 | 28.8 |
| H.J.-4383-4189 x Landhafer | 6666 | 1 | 2 | 7 | 1 | 6 | 2 | 0 | 25 | 17 | 10 | 29.4 |
| Minn. 48-8 x Southland | 7023 | | | | | | 1 | 2 | 10 | 9 | 15 | 30.5 |
| Victorgrain 48-93 | 6986 | 2 | 2 | 32 | 4 | 33 | 3 | 4 | 40 | 51 | 30 | 31.1 |
| Trisp x $Cl^2$-S.Fe x Atl.x$Cl^2$-S.Fe | 6755 | 1 | 4 | 8 | 4 | 9 | | | | | | 32.0 |
| Red Rustproof # 14 | 4876 | 2 | 0 | 16 | 1 | 22 | 2 | 3 | 30 | 37 | 17 | 32.5 |
| Fla. 167 x Santa Fe-Clinton | 6754 | 2 | 2 | 4 | - | - | | | | | | 33.3 |
| Sunland | 6600 | 3 | 6 | 30 | 6 | 16 | 3 | 5 | 39 | 37 | 10 | 36.2 |
| Nortex Strain | 5872 | 1 | 1 | 10 | 0 | 11 | 2 | 0 | 30 | 38 | 14 | 37.5 |
| Wintok x (H.J.-B.R. x S.Fe) | 7017 | | | | | | 3 | 29 | 63 | 38 | 34 | 40.8 |
| Atlantic x $Cl^2$-S.Fe | 5492 | 1 | 2 | 6 | 5 | 4 | | | | | | 41.2 |
| New Nortex x Landhafer | 6998 | | | | | | 2 | 3 | 39 | 37 | 17 | 41.6 |
| Atlantic x $Cl^2$-S.Fe | 6910 | 1 | 9 | 1 | 0 | 11 | | | | | | 42.9 |
| Tenn. 0-90 x Bond | 6732 | 1 | 10 | 2 | 2 | 13 | | | | | | 44.4 |
| Atlantic x $Cl^2$-S.Fe | 6605 | 1 | 10 | 5 | 2 | 9 | | | | | | 46.2 |
| Floriland | 6588 | 3 | 7 | 24 | 18 | 12 | 3 | 13 | 42 | 37 | 8 | 46.6 |
| CI 4658 x $Cl^2$-S.Fe | 6583 | 1 | 5 | 8 | 11 | 10 | | | | | | 47.0 |
| Letoria | 3392 | 1 | 11 | 1 | 2 | 13 | | | | | | 48.1 |
| Tenn. 0-90 x Bond | 6731 | 1 | 8 | 6 | 5 | 8 | | | | | | 48.1 |
| Camellia | 4079 | 1 | 1 | 2 | 1 | 10 | 1 | - | - | 15 | 6 | 48.6 |
| Letoria x $Cl^2$-S.Fe | 6996 | | | | | | 2 | 34 | 29 | 20 | 26 | 49.5 |
| Victorgrain - Res. Miss. | 6977 | | | | | | 2 | 2 | 27 | 39 | 11 | 51.9 |
| (H.J. x B.R. x S.Fe) x South | 7013 | | | | | | 3 | 31 | 15 | 31 | 37 | 54.4 |
| Fulwin Composite | 6993 | | | | | | 2 | 15 | 9 | 13 | 14 | 54.9 |
| Vic.-H.B. x Fulghum-Vic. | 6719 | 1 | 4 | 14 | 2 | 10 | 2 | 33 | 8 | 32 | 12 | 61.7 |
| Atlantic x $Cl^2$-S.Fe | 6985 | | | | | | 1 | 13 | 5 | 7 | 7 | 62.5 |
| Alamo | 5371 | 2 | 3 | 14 | 9 | 10 | 3 | 42 | 9 | 37 | 15 | 65.5 |
| Atlantic x $Cl^2$-S.Fe | 7019 | | | | | | 1 | 11 | 2 | 7 | 7 | 66.6 |
| " " " | 6604 | 1 | 8 | 6 | 10 | 3 | | | | | | 66.6 |
| Letoria x $Cl^2$-S.Fe | 7016 | | | | | | 1 | 14 | 1 | 13 | 10 | 71.0 |
| Bonda x H.J.-S.Fe x Southland | 7012 | | | | | | 1 | 18 | 7 | 14 | 6 | 71.1 |
| Atl.-$Cl^2$-S.Fe x Cl. 4024 | 6922 | 2 | 7 | 3 | 8 | 7 | 1 | 6 | 0 | 11 | 2 | 72.7 |
| Wintok x $Cl^2$-S.Fe | 6740 | 1 | 9 | 0 | 12 | 2 | 3 | 31 | 10 | 33 | 14 | 76.6 |
| Southland | 5207 | 3 | 22 | 17 | 31 | 5 | 3 | 46 | 7 | 51 | 16 | 76.9 |
| Atlantic x $Cl^2$-S.Fe | 6997 | | | | | | 2 | 26 | 6 | 41 | 8 | 82.7 |
| Fultex | 3531 | 1 | 20 | 4 | 12 | 3 | 2 | 36 | 2 | 34 | 9 | 85.0 |
| Atlantic x $Cl^2$-S.Fe | 7018 | | | | | | 1 | 6 | 0 | 18 | 4 | 85.7 |
| Trisp. x $Cl^2$-S.Fe. | 6601 | 1 | 6 | 1 | - | - | | | | | | 85.7 |
| Stanton Strain 1 | 3855 | 1 | 11 | 1 | 8 | 4 | 2 | 25 | 0 | 29 | 7 | 85.8 |
| DeSoto | 3923 | 1 | 6 | 3 | 3 | 4 | 2 | 30 | 0 | 39 | 5 | 86.6 |
| Tennex x Vic. H.B. | 6994 | | | | | | 2 | 37 | 0 | 22 | 9 | 86.7 |
| Atlantic | 4599 | 1 | 17 | 2 | 20 | 0 | 3 | 28 | 2 | 43 | 9 | 89.3 |
| Fulwin Composite | 6995 | | | | | | 2 | 37 | 0 | 29 | 6 | 91.6 |
| Victorgrain x Land. 27 M. Sel. | | | | | | | | 32 | 1 | 37 | 2 | 95.8 |

days before planting. Enough inoculum was applied to darken each groat and leave a small residue of spores in each envelope. The seeds were sown in 5-foot rows in early November. The entries usually were grown in duplicate. At heading time all plants were pulled, examined and recorded as smutted or smut-free. No winter killing was observed during either season at Tifton, but dehulling the seeds reduced stands.

## Results

Table 1 shows percentages of infection of oat varieties and selections ranging from the most resistant to the most susceptible to both collections of smut. Seminole and Coker 53-29 appeared to have outstanding resistance. Delair, which produced only occasional smutted panicles on short and late tillers, also was considered highly resistant. Atlantic, and most crosses derived from Atlantic, are highly susceptible.

Oat varieties and selections from the Texas-USDA cooperative breeding experiments ranged from highly resistant C.I. Nos. 6717, 6744 and 6571 to the highly susceptible Fultex and selections from Fulwin composite crosses. Several selections currently being used as rust-resistant parents also were resistant to the smuts. C.I. 6671, a selection received from the Iowa Experiment Station, is resistant to stem and crown rust, and also was resistant to both smut collections in 1955. Two oat selections received from the Dominion Department of Agriculture of Canada, 3928-5-4 and 3928-5-8, were resistant to stem rust and smuts, but susceptible to crown rust. Minnesota selections C.I. 7098 and C.I. 6909 have shown excellent resistance to the rusts and smuts. Tests in a single season indicated that rust-resistant selections C.I. 6574, C.I. 6582, C.I. 7011 and C.I. 7015 were highly resistant to the Southern oat smuts.

Tifton composite was slightly more virulent than Coker's collection of smuts in 1954, but the reverse was observed in 1955. Tifton composite was more virulent on Lee x Victoria types such as DeSoto, Letoria, Stanton 1, and certain derivatives of Letoria and Atlantic. Coker's collection was consistently more virulent on Red Rustproof types.

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# SEPTORIA REACTIONS OF ENTRIES IN THE NORTH CENTRAL STATES UNIFORM OAT YIELD NURSERY AND OTHER STRAINS IN 1955

A. L. Hooker[1]

## Abstract

Significant differences in varietal reaction to the leaf, stem, and kernel infection phases of the Septoria disease of oats incited by Septoria avenae Frank were found among 153 oat varieties or selections grown and inoculated at Madison, Wisconsin, in 1955. Significant correlations were measured in varietal reaction to the three phases of the disease. Low infection percentages were expressed by several strains.

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The Septoria disease of oats incited by Septoria avenae Frank, the imperfect stage of Leptosphaeria avenaria G. F. Weber, has become established as an important disease in northern United States and eastern Canada. The pathogen may, under appropriate environmental conditions, infect the leaves, stems, and kernels producing characteristic symptoms. Severe reductions in grain yield (2) and quality may result.

The severity of infection varies from year to year and from location to location. In some oat breeding nurseries the disease is sporadic, offering little opportunity to select for resistance. For this reason, it seemed desirable to test established and potential varieties developed in several breeding programs located in the North Central States and adjacent regions to determine their reaction to the disease. It is the purpose of this report to present the Septoria reactions of numerous oat varieties and new selections under conditions of natural infection and artificial inoculations at Madison, Wisconsin, in 1955. Although only 1 year's data are available, and interpretations are thereby limited, a report is given since it is planned to continue similar evaluations each year and to issue appropriate summaries.

## Materials and Methods

Leaf, stem, and kernel reactions to Septoria avenae in artificial inoculations were obtained on 153 oat varieties or new selections. Three replications of these were systematically planted on April 23 in 3-foot rows with 1 of 6 check varieties planted every tenth row. All plots were inoculated by spraying with a water suspension of spores and mycelium in the evenings of June 1, 8, and 20. A composite of 10- or 12-day old cultures, selected for sporulation and pathogenicity, was used. These were blended in a Waring Blendor at the rate of 1 Petri plate per 100 ml. water and diluted 1:5 for field application. In addition, 10 culms in each row were hypodermically inoculated in the boot- or late shoot-stage between June 14 and 17.

Notes on percentages of leaf infection, on a whole plant basis, were taken on June 17, 27, and 30. The 10 hypodermically inoculated culms were harvested at maturity. The leaves and leaf sheaths were removed and stem infection ratings were taken as percentage of stem area expressing lesions. In addition, similar stem infection ratings were obtained for each plot from 10 culms which had received only a spray inoculation. The panicles from the hypodermically inoculated culms were threshed by hand and percentage of kernels infected recorded.

Natural leaf infection scores were obtained on June 29 on three replications of these strains grown in various yield nurseries in the same field.

Statistical analyses were calculated using all entries in the test.

## Results

Statistically highly significant differences among oat strains in their reaction to Septoria avenae were measured in each evaluation (Table 1). No significant difference in Septoria reaction was measured among sets of the check varieties. Significant correlations were obtained between various paired combinations of leaf, stem, and kernel reactions (Table 2).

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Table 1. Analyses of variance summary for reaction of 153 oat varieties or selections to Septoria avenae.

| Disease evaluation | MS | F | LSD.05 | CV |
|---|---|---|---|---|
| Leaf infection on June 29, natural infection | 94.90 | 4.58** | 7.32 | 17.38% |
| Leaf infection on June 17, spray inoculation | 137.20 | 3.00** | 10.87 | 21.99% |
| Leaf infection on June 30, spray inoculation | 127.92 | 7.22** | 6.76 | 11.25% |
| Stem infection, spray inoculation | 830.75 | 20.74** | 10.17 | 17.72% |
| Stem infection, hypodermic inoculation | 719.84 | 7.45** | 15.19 | 26.26% |
| Kernel infection, hypodermic inoculation | 413.34 | 2.56** | 20.42 | 74.78% |

** Significant at 1% level.

Table 2. Correlation coefficients between paired comparisons of leaf, stem and kernel reactions to Septoria avenae.

| Items correlated | r |
|---|---|
| Leaf infection: natural and on June 30 after spray inoculation | + 0.686** |
| Leaf infection after spray inoculation: June 17 and June 30 | + 0.475** |
| Spray inoculation: Leaf infection on June 30 and Stem infection | + 0.499** |
| Stem infection: Spray inoculation and Hypodermic inoculation | + 0.822** |
| Hypodermic inoculation: Stem infection and Kernel infection | + 0.361** |

** Significant at 1% level.

The leaf, stem, and kernel reactions to Septoria avenae, obtained under various conditions, are presented in Table 3 for the named varieties and all entries in the North Central States uniform oat yield nursery. In addition to those listed, selections of the following crosses expressed low or high leaf (June 30) and stem infections following spray inoculations:

Leaf Infection 32% or less

Clinton Reselect x [Landhafer x (Richland x Bond)]
Vicland x [Garry x (Hawkeye x Victoria)]

Leaf Infection 47% or more

Garry x (Hawkeye x Victoria)
Rodney x [Landhafer x (Forward x Victoria-Richland)]
Vicland x [Branch x (Clinton[2] Santa Fe)]

Stem Infection 15% or less

Clinton Reselect x [Landhafer x (Richland x Bond)]
Clinton[4] x Santa Fe
[Erban x (Richland x Bond)] x Clinton[2] Santa Fe
Garry x $F_1$ [(Forward x Victoria-Richland) x Vicland] x (Hawkeye x Victoria)
Landhafer x (Richland x Bond)
[Spooner x (Bond x Double Cross)] x (Hawkeye x Victoria)
Vicland x (Andrew x Landhafer)

Stem Infection 50% or more

Ajax x (Hawkeye x Victoria)
Clinton[2] Santa Fe x Beacon
(Clinton[2] Santa Fe) x Branch
Clinton[2] Santa Fe x (Hawkeye x Victoria)
(Forward x Victoria-Richland) x Andrew
[(Forward x Victoria-Richland) x Forward] x [Spooner x (Bond x Double Cross)]
Rodney x [Landhafer x (Forward x Victoria-Richland)]
Rodney x (Santa Fe x Clinton[3])
Rodney x Trispernia
Vicland x [Branch x (Clinton[2] Santa Fe)]
Vicland x [Landhafer x (Richland x Bond)]
Vicland x [Vicland x (Landhafer x (Forward x Victoria-Richland))]
(Victoria x Hajira-Banner) x Spooner

Table 3. Leaf, stem, and kernel reactions to Septoria avenae of the entries in the North Central States Uniform Oat Yield Nursery, and other varieties at Madison, Wisconsin in 1955.

| Variety or cross | C.I. No.[a] | % Leaf infection | | | % Stem infection | | % Kernel infection |
|---|---|---|---|---|---|---|---|
| | | natural 6/29 | spray inoculated 6/27 | spray inoculated 6/30 | spray inoculated | hypodermic inoculated | hypodermic inoculated |
| Abegewait | 4970 | 12 | 33 | 26 | 17 | 10 | 7 |
| Ajax | 4157 | 22 | 42 | 28 | 23 | 33 | 1 |
| Andrew | 4170 | 32 | 32 | 38 | 52 | 52 | 1 |
| Andrew x Clinton | 5956 | 25 | 43 | 40 | 15 | 25 | 7 |
| Beacon x Hawkeye-Victoria | 6752 | 25 | 30 | 38 | 18 | 15 | 28 |
| Bentland | 6930 | 30 | 47 | 51 | 43 | 50 | 14 |
| Benton x Marion | 6928 | 37 | 43 | 43 | 65 | 58 | 13 |
| Logan | 6929 | 33 | 42 | 45 | 62 | 57 | 12 |
| (Bond-Rainbow x Hajira-Joanette) x Landhafer | 6913 | 25 | 43 | 42 | 27 | 27 | 7 |
| (Boone-Cartier) x Clinton | 4927 | 33 | 30 | 44 | 40 | 43 | 30 |
| Branch | 5013 | 17 | 40 | 30 | 25 | 27 | 15 |
| Cherokee | 5044 | 33 | 35 | 43 | 35 | 52 | 4 |
| Clarion | 5647 | 30 | 37 | 42 | 65 | 63 | 5 |
| Clintafe | 5869 | 22 | 35 | 28 | 17 | 23 | 3 |
| Clintland | 6701 | 25 | 33 | 32 | 5 | 13 | 3 |
| Clinton | 3971 | 27 | 38 | 32 | 7 | 8 | 1 |
| Clinton 59 | 4259 | 25 | 32 | 40 | 6 | 15 | 7 |
| Clinton[2] x Arkansas 674 | 6644 | 23 | 27 | 38 | 22 | 23 | 17 |
| Clinton x (Boone-Cartier) | 6868 | 23 | 28 | 36 | 28 | 27 | 48 |
| Clinton x (Boone-Cartier) | 6933 | 28 | 32 | 38 | 38 | 33 | 25 |
| Clinton x Landhafer | 5864 | 25 | 33 | 44 | 42 | 37 | 7 |
| Clinton x [Victory x (Victoria x Hajira-Banner)] | 7030 | 28 | 32 | 42 | 35 | 28 | 20 |
| Clinton x [Victory x (Victoria x Hajira-Banner)] | 7020 | 20 | 37 | 32 | 37 | 33 | 25 |
| Clinton x Ukraine | 6637 | 28 | 32 | 40 | 42 | 50 | 9 |
| Clinton x Ukraine | 6638 | 23 | 37 | 42 | 42 | 37 | 4 |
| D69-Bond x (Victoria-Richland x Bannock) | 7117 | 27 | 28 | 38 | 40 | 30 | 2 |
| Garry | 6662 | 22 | 37 | 32 | 30 | 23 | 3 |
| Gopher | 2027 | 23 | 37 | 33 | 5 | 17 | 2 |
| Jackson | 5441 | 28 | 40 | 35 | 33 | 25 | 1 |
| [Landhafer x (Mindo x Hajira-Joanette)] x Andrew | 6878 | 35 | 42 | 42 | 62 | 62 | 7 |
| [Landhafer x (Mindo x Hajira-Joanette)] x Andrew | 7083 | 25 | 33 | 35 | 18 | 33 | 4 |
| [Landhafer x (Mindo x Hajira-Joanette)] x Andrew | 7084 | 27 | 35 | 38 | 38 | 45 | 2 |
| [Landhafer x (Mindo x Hajira-Joanette)] x Andrew | 6936 | 25 | 28 | 36 | 25 | 37 | 19 |
| [Landhafer x (Mindo x Hajira-Joanette)] x Clinton | 6935 | 27 | 35 | 35 | 8 | 20 | 3 |
| Marion x D69-Bond | 7116 | 22 | 32 | 37 | 53 | 55 | 12 |
| Minland | 6765 | 43 | 48 | 51 | 40 | 38 | 28 |
| Mo. 0-205 | 4988 | 27 | 40 | 38 | 47 | 38 | 10 |
| Nemaha | 4301 | 28 | 32 | 37 | 28 | 35 | 22 |
| Nemaha x (Clinton x Boone-Cartier) | 6934 | 25 | 33 | 36 | 53 | 57 | 30 |
| Newton | 6642 | 25 | 40 | 40 | 50 | 47 | 18 |
| Rodney | 6661 | 22 | 35 | 40 | 53 | 42 | 14 |
| [Moxton x (Victoria x Hajira-Banner)] x Ajax x(Victoria x Hajira-Banner)] | 5951 | 22 | 35 | 31 | 48 | 43 | 10 |
| [Moxton x (Victoria x Hajira-Banner)] x Ajax x (Victoria x Hajira-Banner)] | 5952 | 25 | 28 | 31 | 53 | 53 | 2 |
| Ransom | 5927 | 38 | 27 | 40 | 53 | 53 | 32 |
| Sauk | 5946 | 25 | 40 | 35 | 45 | 38 | 22 |
| Shefford | 6913 | 23 | 33 | 33 | 30 | 25 | 3 |
| Simcoe | 6767 | 20 | 38 | 32 | 22 | 23 | 12 |
| State Pride | 1154 | 25 | 30 | 38 | 25 | 35 | 4 |
| Vicland | 3611 | 32 | 38 | 39 | 7 | 23 | 21 |
| Vicland x (Branch x Clinton[2]-Santa Fe) | 6916 | 35 | 28 | 39 | 50 | 45 | 28 |
| (Victoria x Hajira-Banner) x Spooner | 6939 | 23 | 28 | 37 | 22 | 35 | 12 |
| Waubay | 5440 | 28 | 42 | 40 | 50 | 45 | 8 |

[a] Refers to accession number of Cereal Crops Section, Field Crops Research Branch.

Strains C.D. 920 (Avena brevis), C.D. 1002 (A. brevis), C.D. 1007 (A. strigosa), C.D. 3820 (A. strigosa), C.D. 4090 (A. sativa) and C.D. 5022 (A. sativa) previously reported by Derick (1) to be resistant under conditions of natural infection in eastern Canada, showed 22 percent or less leaf infection and 7 percent or less stem infection following the artificial inoculations employed in this study. They were, however, 5 to 10 days later in heading than most of the named varieties.

## Discussion

Although varietal differences in reaction were expressed in all phases of the Septoria disease and the varietal reaction in the several phases appeared to be somewhat associated, the most distinct strain differences were in degree of stem infection. Stem infection readings following hypodermic inoculations were higher on the average than readings following a spray inoculation, but variability was greater and a larger difference between varieties was required for significance.

The coefficient of variability was very high in the kernel infection evaluation and a difference of 20 percent or more between strains was required for significance at the 5 percent level. Nevertheless, some varietal differences in kernel infection were evident.

Higher levels of leaf infection were obtained with artificial inoculation than with natural infection, but the ranking of the varieties was similar in each. Higher readings after artificial inoculation were generally obtained on June 30 than on June 17. Occasionally the later maturing oat strains would show less leaf infection on June 30 than they did on June 17. This may be due to the emergence of the upper leaves after the more favorable environmental conditions for infection had passed.

Leaf and stem readings on a number of oat selections grown in this test, although higher, compared favorably with those obtained following natural infection when the selections were grown elsewhere in the State. This suggests that the inoculation techniques employed were reliable in measuring the comparative ability of oat strains to resist or escape infections by Septoria avenae.

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# SOURCES OF RESISTANCE TO POWDERY MILDEW OF BARLEY

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## Summary

One hundred and twenty entries selected from 6,273 entries in the world collection of barley were tested with 8 physiological races of powdery mildew collected from various areas of North America. Most of the resistant new introductions were spring types from India, France, and Germany, and winter types from Germany. Sixteen varieties are listed that either have one gene for resistance, or were highly resistant in the field as well as in the greenhouse. These have been crossed with widely adapted spring and winter varieties to add those sources of resistance to the adapted varieties.

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Powdery mildew of barley, caused by Erysiphe graminis hordei Em. Marchal, is an important disease of barley. It is considered to be one of the most serious diseases in the winter barley-producing area of the United States. Schaller (19) found that in California a severe infection on a susceptible selection caused a reduction of 27.4 percent of the total yield of a resistant selection.

Honecker (10) estimated that on the basis of experiments in Germany there was about a 10 percent increase in yield associated with resistance. Although they did not estimate the amount of loss in yield, Hiura and Heta (9) stated that considerable damage results each year in Japan from powdery mildew.

The 6,273 entries in the world collection of barley maintained by Field Crops Research Branch, Agricultural Research Service, United States Department of Agriculture, were tested to locate additional germ plasm with resistance to powdery mildew found in North America. The cultures of the organism were obtained from diseased plant material supplied by research men at several locations in North America. Varieties with known genes for resistance, or that had been outstanding for resistance in field and greenhouse tests, were crossed with widely adapted winter and spring varieties to add those sources of resistance to the adapted varieties.

## Review of Literature

Physiological races of Erysiphe graminis hordei were first demonstrated by Mains and Dietz in 1930 (12). Since that time 12 physiological races of the organism have been reported in North America (6, 15, 21). Two races have been observed in Argentina (8) and 3 races, and 2 biotypes of race 8 found in North America, have been isolated in Japan (9) that are distinctly different from the races in North America. Honecker (11) isolated 9 races in Germany. Since he did not use the same differential varieties as the other workers, the relationship of his races with those of other investigators is not known.

Several varieties and selections have been found by Mains and Dietz (12), Dietz (7), Mains and Martini (13), Tidd (21), Newton and Cherewick (15), and Poehlman (18) that are resistant to certain races of powdery mildew found in North America. The Japanese workers (16) found resistance in many of the 807 varieties and selections they tested with a mixture of races collected in Okayama prefecture. Sarasola, Favret, and Vallega (18) in Argentina reported the reaction of barley varieties to Argentina race 1.

Since Biffen (1) in 1907 made his cross between mildew-susceptible Hordeum vulgare and mildew-resistant H. spontaneum, numerous sources of resistance have been located. As the result of the studies by Briggs and his coworkers (2, 3, 4, 5, and 20) and Favret (8), 12 genes for resistance to powdery mildew are known. Nine of these genes are either dominant or incompletely dominant for resistance and 3 are recessive.

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The author wishes to express his appreciation to D. J. Ward for supplying the seed for this study; to Harland Stevens for growing selected entries at Aberdeen, Idaho; to C. W. Schaller for furnishing the cultures of the two races of powdery mildew from California; and to the many individuals who sent him diseased plant material from which cultures of the organism were isolated.

Table 1. The seedling reaction of 120 varieties and selections of barley to eight physiological races of powdery mildew.

| C.I. No.[a] | Variety or selection | Origin | Description[b] | Habit of growth[c] | Reaction[d] to race | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Race: 3 | Race: 8 | Race: 9 | Race: 12 | Race: 4 | Calif. new | Race: 14 | Race: 11 |
| 704 | Popeline | Caucasus | 6 Bk R C S | W | 1 | 1 | 2 | 0-1 | 1 | 0-1 | 0-1 | 1-2 |
| 733 | Kharsila | India | 6 W R N S | S | 0-1 | 1-2 | 1 | 0-1 | 1 | 1 | 0 | 0 |
| 906 | Hanna | Germany | 2 W R C L | S | 1-2 | 1 | 4 | 4 | 0-1 | 4 | 0 | 0-1 |
| 928 | Goldfoil | Plant Sel. | 2 W SS C L | S | 0-1 | 0-1 | 0-1 | 4 | 0-1 | 4 | 0-1 | 0-1 |
| 1009 | Wofut | Russia | 6 BK R C S | W | 1-2 | 0-1 | 1-2 | 1 | 1-2 | 0-1 | 0 | 1-2 |
| 1014 | Eremo | India | 6 W R N L | S | 1 | 0-1 | 1 | 0-1 | 0-1 | 0-1 | 2 | 0-1 |
| 1015 | Ederle | do | 6 B2 R N L | S | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0-1 |
| 1016 | Kwan | do | 6 B1 R C L | S | 4 | 2 | 2 | 3-4 | 2 | 1-2 | 1-2 | 1-2 |
| 1017 | Monte Cristo | do | 6 B2 R C L | S | 0-1 | 1 | 0-1 | 0-1 | 0-1 | 0-1 | 1 | 1 |
| 1083 | Irisaka | do | 2 P R N L | S | 3-4 | 1 | 1 | 1 | 1 | 0-1 | 1 | 1 |
| 1085 | Dehra | do | 6 B3 R N S | S | 0-3 | 0-1 | 0-1 | 0-1 | 1 | 0 | 0 | 1-2 |
| 1091 | Gopal | do | 2 P R N L | S | 0-1 | 1 | 1 | 1 | 1 | 0-1 | 1 | 1 |
| 1179 | Algerian | Algeria | 6 B1 R C S | S | 0-1 | 1 | 1 | 0-1 | 0-1 | 0-1 | 0-1 | 1 |
| 1264 | Donjon | Mexico | 6 BK R C S | SW | 1 | 0-1 | 1-2 | 1 | 1 | 0 | 0 | 0-1 |
| 2045 | Rialto | Iran | 2 B2 R C L | S | 1 | - | 2 | 3-4 | 0-1 | 0-1 | 1 | 2 |
| 2202 | Black Russian | Tiflis | 6 BK R C S | W | 1 | 1 | 2 | 0-1 | 0-1 | 1 | 0-1 | 1 |
| 2239 | Eremo | India | 6 W R N L | SW | 0-1 | 1 | 1 | 0 | 0-1 | 0-1 | 0-1 | 0-1 |
| 2250 | Purple Nudum | do | 2 P R N L | S | 1 | 1 | 1 | 1-2 | 1 | 1 | 1 | 1-2 |
| 2318 | Kharsila | do | 6 W R N S | S | 1-2 | 1 | 1-2 | 1 | 1 | 0-1 | 0 | 1-2 |
| 2483 | Modia | N. Africa | 6 B2 R C S | S | 0-1 | 1 | 1 | 1 | 1 | 0-1 | 1 | 0-1 |
| 2612 | Algeria | Minnesota | 6 B2 R C S | S | 1 | 1 | 1 | 0-1 | 0-1 | 0-1 | 0-1 | 0-1 |
| 3212 | Modjo | Ethiopia | D B2 R C L | S | 1 | 1-2 | 1 | 1 | 1 | 1 | 1 | 1-2 |
| 3212-1 | | do | D B2 R C S | S | 1 | 1 | 0-1 | 1 | 1 | 1 | 1 | 1-2 |
| 3214 | | Turkestan | 6 BK R C S | W | 0 | 1-2 | 1-2 | 1 | 1 | 0 | 1 | 1 |
| 3395 | Lyallpur BS | India | 6 B1 R C L | S | 4 | 0-1 | 1 | 1 | 1 | 1 | 0-1 | 0 |
| 3396 | Hoshiarpur | do | 6 B2 R C L | S | 1 | 0-1 | 1 | 0-1 | 0-1 | 1 | 0-1 | 1 |
| 3398 | Kulu | do | 6 W R N L | S | 0-1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 |
| 3400 | Mianwali | do | 6 B1 R C L | S | 0-1 | 1 | 0-1 | 0-1 | 1 | 0-1 | 1 | 1 |
| 3401 | Multan | do | 6 B3 R C L | S | 0-1 | 1 | 1 | 0-1 | 1 | 1 | 0-1 | 1 |
| 3405 | Balouchistan | do | 6 B2 R C L | S | 0-1 | 1 | 0-1 | 0-1 | 0 | 1 | 1 | 1 |
| 3407 | Black BS | do | 2 P R N L | S | 1 | 1 | 1 | 0-1 | 1 | 0 | 1 | 1-2 |
| 3527-2 | Villa | Spain | 6 W R C S | SW | 2 | 1 | 1 | 2 | 1 | 1 | 1 | 2 |
| 3530-2 | Alagon | do | 6 B3 R C S | SW | 2 | 1 | 2 | 2 | 1 | 1 | 1 | 2 |
| 3573 | Roho | Mariout, Egypt | 2 B2 R C L | S | 1 | 1 | 1 | 1-2 | 1 | 1-2 | 4 | 1-2 |
| 3609 | Palmella Blue | do | 2 B2 SS C L | S | 1 | 1 | 1 | 1-2 | 1 | 1 | 0-1 | 1 |
| 3623 | | do | 2 B1 R C L | S | 1 | 0-1 | 1 | 1-2 | 1 | 2 | 1 | 1 |
| 3704 | | do | 2 B1 R C L | S | 1 | 1 | 1 | 2 | 1 | 2-3 | 1 | 0-1 |
| 3725 | | do | 2 B1 R C S | S | 1 | 1 | 1 | 1 | 1 | 0-1 | 1 | 1 |
| 3726 | Retu | do | 2 B2 SS C L | S | 1 | 1 | 1 | 1-2 | 1-2 | 1 | 1-2 | 1-2 |
| 3751 | Persistawn | do | 2 B1 R C L | S | 1 | 1 | 1 | 1-2 | 1 | 1 | 1 | 1-2 |
| 3764 | | do | 2 B1 R C L | S | 1 | 1 | 0-1 | 2 | 0-1 | 2-3 | 1 | 1 |
| 3933 | Vagabond | India | 6 B1 R C L | S | 1 | 0 | 0-1 | 0-1 | 0 | 1 | 0-1 | 1 |
| 4147-2 | Duab | Afghanistan | 6 W R C L | S | 0-1 | 0-1 | 1 | 2 | 0 | 1 | 1 | 1-2 |
| 4193 | | Algeria | 6 W R C L | S | 2-3 | 1 | 1 | 3 | 1 | 2 | 1-2 | 2 |
| 4217 | | India | 6 W R C L | - | 1 | 1 | 1 | 0 | 0-1 | 1 | 1 | 1-2 |
| 4219 | | Ethiopia | D B1 R C L | S | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 4220-1 | | do | D B2 R C L | S | 1 | 1 | 1 | 1 | 1 | 1-2 | 1 | 1 |
| 4293 | | Transcaucasia | 6 BK R C S | W | 1 | 1-2 | 1-2 | 1 | 0 | 1-2 | 1 | 0-1 |
| 4302-1 | | do | 6 W R C S | W | 1 | 1 | 1 | 0-1 | 0-1 | 1 | 1 | 1-2 |
| 4314 | | do | 6 BK R C S | W | 1 | 1 | 1 | 0-1 | 0-1 | 0-1 | 1 | 1-2 |
| 4326-2 | | do | 6 B3 R C S | W | 0 | 0-1 | 1-2 | 2 | 0-1 | 0-1 | 0-1 | 1-2 |
| 4341 | | Egypt | 6 W R C L | - | 1 | 1 | 0-1 | 0-1 | 0-1 | 1 | 1 | 0-1 |
| 4341-1 | | do | 6 W R C L | - | 0-1 | 0-1 | 1 | 0 | 0-1 | 0-1 | 1 | 0,4 |
| 4343-1 | Spiti | Tibet | 6 B2 R N L | S | 0-1 | 0-1 | 0 | 0-1 | 0-1 | 0 | 0 | 2-3 |
| 4355 | Rupee | India | 6 B1 R C L | S | 0 | 0-1 | 1 | 0-1 | 0-1 | 0 | 0-1 | 0-1 |
| 4356 | | Ethiopia | I W R C S | S | 1 | 0-1 | 0 | 2 | 1 | 0 | 1 | 2 |
| 4968 | | Iraq | 2 B1 SS C S | S | 0-1 | 1 | 0-1 | 0-1 | 1 | 1 | 1-2 | 1 |
| 4968-2 | | do | 2 B2 S C S | S | 0-1 | 1-2 | 1-2 | 0-1 | 0-1 | 0-1 | 1-2 | 0-1 |
| 4979 | Rabat | Morocco | 6 B1 R C L | S | 0 | 0-1 | 1 | 0-1 | 0 | 0 | 0 | 0-1 |
| 5631 | Awnless | Kubanska | 6 B2 A C L | SW | 1-2 | 1-2 | 3 | 0-1 | 1 | 1 | 1-2 | 2 |
| 5644 | Caspian | do | 6 W R C L | SW | 1 | 1 | 1-4 | 1-2 | 1 | 1-2 | 1 | 2 |
| 5645 | Tradak | do | 6 BK A C L | S | 0-1 | 0-1 | 1-2 | 0 | 1 | 0-1 | 1 | 1 |
| 5647 | Marco | do | 6 W R C L | W | 1 | 1 | 1-4 | 0-1 | 1 | 1 | 1 | 2 |
| 5799 | | Ethiopia | D P R C S | S | 1 | 0-1 | 0 | 2-3 | 1-2 | 1-2 | 1 | 2 |
| 5862 | Menelik | do | D B2 R C L | S | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0-1 |

Table 1. Continued

| C.I. No.[a] | Variety or selection | Origin | Description[b] | Habit of growth[c] | Reaction[d] to race | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Race 3 | Race 8 | Race 9 | Race 12 | Race 4 | Calif. new | Race 14 | Race 11 |
| 5863 | | do | D B2 R C L | S | 1 | 1 | 1 | 1 | 1 | 1-2 | 1 | 1 |
| 5864 | | do | D B1 R C L | - | 1 | 0-1 | 2 | 1-2 | 0-1 | 0-1 | 1 | 0-1 |
| 5865 | | do | D P R C S | - | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 4 |
| 6121 | | India | 6 B2 R N L | S | 1 | 1-2 | 1 | 0-1 | 0-1 | 0 | 0-1 | 0-1 |
| 6159 | Brittle Rachis | Hybrid | 2 W R C L | S | 1-2 | 0-1 | 0-1 | 4 | 0 | 4 | 1 | 2 |
| 6168 | Long Glumes | do | 2 W R C L | S | 0-1 | 0-1 | 1 | 0 | 1 | 0-1 | 1 | 0-1 |
| 6179 | Weak Two Rowed | do | 2 B2 R C S | S | 0-1 | 0-1 | 0-1 | 0-1 | 1 | 1 | 0-1 | 1 |
| 6225 | | Turkey | 2 W SS C L | S | 1 | 2-3 | 2 | 1 | 1 | 1 | 2 | 4 |
| 6305 | Psaknon | Australia | 6 B1 SS C S | S | 1-2 | 1-2 | 1-2 | 1 | 1-2 | 1-2 | 1 | 0-1 |
| 6306 | Ricardo | Uruguay | 2 B1 R C L | S | 0-1 | 1 | 1 | 0-1 | 1 | 1 | 1 | 1 |
| 6316 | Durani | Afghanistan | 6 B1 R C S | S | 0-1 | 1 | 0 | 0 | 1 | 0-1 | 1 | 1 |
| 6402 | | Poland | 2 W R C L | S | 0-1 | 0-1 | 0-1 | 4 | 0-1 | 3-4 | 0-1 | 1 |
| 6590 | | Afghanistan | 6 B2 R C L | W | 1 | 1 | 1 | 0-1 | 0-1 | 0-1 | 1 | 1 |
| 6600 | | do | 6 B3 R C L | S | 1 | 1-2 | 1-2 | 0-1 | 1 | 0 | 1 | 2 |
| 6683 | | Gonzali,USSR | 6 BK R C S | W | 4 | 1 | 1 | 0-1 | 1 | 0-1 | 0-1 | 1 |
| 7021 | Queens | New Jersey | 6 W S C L | S | 1 | 0-1 | 0 | 1-2 | 0 | 1-2 | 1 | 1 |
| 7190 | | Ethiopia | I W R C S | S | 1 | 1 | 1-2 | 1-2 | 1 | 0-1 | 1 | 1 |
| 7193 | | do | 6 W R C S | S | 1 | 0-1 | 1-2 | 2 | 1 | 0-1 | 1 | 1-2 |
| 7207 | | do | I W R C S | S | 1 | 1 | 0 | 2 | 1 | 0 | 1 | 1-2 |
| 7323 | Atlas 46 | California | 6 W R C S | S | 1 | 1 | 1 | 3-4 | 0-1 | 3 | 0-1 | 0 |
| 7555 | Engledow India | Argentina | 6 B2 R C L | S | 1 | 1 | 1 | 0 | 0-1 | 0-1 | 2 | 1 |
| 7573 | Tuck | Kentucky | 6 B2 R C S | W | 1 | 1-2 | 1-2 | 1 | 1-2 | 1 | 1-2 | 4 |
| 7610 | | India | 6 B2 R C L | S | 1 | 1-2 | 1 | 1 | 1-2 | 1 | 1 | 2 |
| 7619 | | do | 6 B2 R C L | S | 2 | 0-1 | 1-2 | 0-1 | 1 | 1-2 | 1 | 1 |
| 7672 | | do | 6 W R C L | S | 0-1 | 1 | 0-1 | 0-1 | 0-1 | 0-1 | 0-1 | 1 |
| 7684 | | do | 6 B2 R C L | S | 0-1 | 0-1 | 0 | 0-1 | 1 | 0-1 | 0-1 | 1 |
| 7728 | | do | 6 W R C L | S | 1 | 0-1 | 1 | 1 | 0 | 0-1 | 1 | 1 |
| 7737 | | do | 6 W R C L | S | 1 | 1 | 0 | 0 | 0-1 | 0-1 | 0-1 | 1 |
| 7738 | | do | 6 W R C L | S | 0-1 | 1 | 1-2 | 0 | 0-1 | 0 | 1 | 1 |
| 7746 | | do | 6 W R C L | S | 1 | 0-1 | 1 | 0-1 | 1 | 0-1 | 1 | 1 |
| 7751 | | do | 6 B2 R N L | S | 0 | 0-1 | 1 | 0-1 | 0 | 0-1 | 1 | 0-1 |
| 7755 | | do | 6 W R C L | S | 1 | 0-1 | 0-1 | 0-1 | 0 | 0 | 0-1 | 1 |
| 7759 | | do | 6 W R C L | S | 0-1 | 0-1 | 0 | 0-1 | 0-1 | 0-1 | 1 | 1 |
| 7765 | | do | 6 W R C L | S | 1 | 0-1 | 0 | 0 | 0-1 | 0-1 | 0-1 | 0-1 |
| 7766 | | do | 6 W R C L | S | 0-1 | 0-1 | 0 | 0 | 4 | 0 | 0-1 | 4 |
| 7771 | | do | 2 P R N L | S | 1 | 1-2 | 1 | 0-1 | 1 | 1 | 1 | 0-1 |
| 7845 | | Turkey | 6 B3 R C S | S | 2 | 1 | 1-2 | 1 | 1-2 | 2 | 1 | 1-2 |
| 8051 | Stephan | Germany | 2 W R C L | S | 1 | 0-1 | 1 | 4 | 0 | 4 | 0-1 | 1 |
| 8301 | Colmar 106 | France | 2 W SS C L | S | 0-1 | 0-1 | 0 | 4 | 0 | 2 | 0 | 1 |
| 8302 | Colmar 142 | do | 2 W R C L | S | 0-1 | 0-1 | 0 | 2 | 0-1 | 2-3 | 1 | 2 |
| 8323 | Schribaux 227 | do | 6 W R C L | S | 1-2 | 2 | 1 | 4 | 1-2 | 1-2 | 2 | 0-1 |
| 8330 | Morocaine 021 | do | 6 B1 R C S | S | 2 | 1-2 | 1-2 | 1-2 | 2 | 0 | 1-2 | 1-2 |
| 8334 | Morocaine 079 | do | 6 B1 R C L | S | 0 | 0-1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8503 | | India | 6 B2 R N L | SW | 0 | 0-1 | 0 | 0-1 | 0-1 | 0 | 0 | 0-1 |
| 8808 | 930/48 | Germany | 6 B3 R C L | W | 1 | 0-1 | 1 | 0 | 0 | 0-1 | 1 | 0-1 |
| 8809 | Wedlim | do | 6 W R C S | W | 0 | 0-1 | 1 | 0 | 0 | 0-1 | 1 | 1 |
| 8810 | 1281/48 | do | 6 B3 R C L | W | 0 | 0-1 | 1 | 1 | 0 | 1 | 1 | 0-1 |
| 8811 | Pranger | do | 6 B3 R C S | W | 1 | 0-1 | 1 | 1 | 0-1 | 1 | 1 | 0-1 |
| 8826 | 6229/37 | do | 2 W R C L | S | 0-1 | 0-1 | 0 | 0-1 | 0 | 1 | 1 | 0-1 |
| 8827 | 6479/37 | do | 2 B1 R C L | S | 0 | 0-1 | 0 | 0-1 | 0 | 0 | 0 | 0 |
| 8828 | 7361/44 | do | 2 W R C L | S | 0-1 | 1 | 1 | 0-1 | 0-1 | 1 | 1 | 1 |
| 8829 | 8053/43 | do | 2 W R C L | S | 0 | 0-1 | 0 | 0-1 | 0 | 0-1 | 0-1 | 0-1 |
| 8831 | 6705/37 | do | 2 W R C L | S | 0 | 0-1 | 1 | 0-1 | 0 | 1 | 1 | 1 |
| 8832 | 828/45 | do | 2 W R C L | S | 0 | 0-1 | 0-1 | 0-1 | 0 | 1 | 1 | 0 |
| 8836 | | India | 6 B3 R N L | S | 0 | 0-1 | 0 | 0-1 | 0 | 0 | 0-1 | 0-1 |

[a] C.I. refers to accession numbers of Cereal Crops Section, Field Crops Research Branch.

[b] Column 1: 6 = 6-rowed, 2 = 2-rowed, D = deficiens, I = irregulare.
Column 2: Kernel color -- B = blue, W = white, BK = black, P = purple
Column 3: Awn type -- R = rough, SS = semismooth, S = smooth, A = awnless.
Column 4: Kernel type -- C = covered, N = naked.
Column 5: Rachilla hairs -- L = long, S = short.

[c] W = winter, SW = semiwinter, S = spring.

[d] 0 = immune, 1 = highly resistant, 2 = moderately resistant, 3 = moderately susceptible, 4 = susceptible, 1-4 = mesothetic.

Table 2. The sixteen resistant varieties that have been crossed on widely adapted spring and winter barley varieties.

| C. I. No. | Resistant varieties | Gene for resistance[1/] | Adapted variety | | |
|---|---|---|---|---|---|
| | | | Manchuria C. I. 2330 | Randolph C. I. 6372 | Reno C. I. 6561 |
| 906 | Hanna | $ML_h$ | X[2/] | - | X |
| 928 | Goldfoil | $ML_g$ | X | X | - |
| 1016 | Kwan | $ML_k$ | X | X | X |
| 1017 | Monte Cristo | $ML_m$ | X | - | - |
| 1179 | Algerian | $ML_a$ | X | X | - |
| 2202 | Black Russian | $ML_b$ | X | - | - |
| 2483 | Modia | - | X | - | - |
| 3400 | Mianwali | - | X | X | X |
| 3401 | Multan | | X | X | - |
| 3609 | Palmella Blue | - | X | - | - |
| 4979 | Rabat | - | X | X | X |
| 6168 | Long Glumes | - | X | - | - |
| 6305 | Psaknon | $ML_p$ | X | X | X |
| 6306 | Ricardo | | X | X | - |
| 6316 | Durani | | X | - | X |
| 8811 | Franger | - | X | - | X |

[a] Genes for resistance to California Race 3 or Argentina Race 1.

[b] The X indicates the cross has been made between the resistant variety and the adapted variety.

## Material and Methods

The 6,273 entries from the world collection of barley were tested in the greenhouse with a composite of races 4, 9, and 14, a new race isolated from plants grown at Ottawa, Canada. Five grams of each entry from the barley collection were furnished by D. J. Ward. Seed used in subsequent years were obtained from plants grown in North Carolina or at Aberdeen, Idaho.

The cultures of powdery mildew used in this study were isolated from either conidia on living plants or cleistothecia on dried leaves. This material was supplied by research men in various parts of North America. The cultures used were from single pustules with the exception of cultures used in 1954 which were from single spores. All tests were carried out in the greenhouse during the months of December through March when the temperature could be kept near 70° F. The seedlings were inoculated in the first or second leaf stage by shaking spores from infected plants onto seedlings in 3-inch pots on open benches. Readings were made 7 to 10 days following inoculation. Each reading reported is from two separate inoculations with the same race.

The first generation hybrid seed of the crosses involving the adapted spring and winter varieties were grown at Aberdeen, Idaho. The advanced generations were then grown in North Carolina. The tests to identify the progenies homozygous for the gene for resistance were carried out by seedling tests with a culture of California race 3.

## Results

When 6,273 entries from the world collection of barley were tested in the greenhouse in the fall of 1950 to a composite of races 4, 9, and 14, 229 gave a resistant reaction.

During the winters of 1951-52, 1952-53, and 1953-54, 205 of the 229 entries were retested to individual races in the greenhouse. In 1951-52 the inoculum used included races 3, 4, 8, 9, 12, 14, and a new race from California. In 1952-53 races 3, 4, 9, 11, and 12 were used. In 1953-54 all 8 races included in this study were tested.

During the winter of 1954-55 those entries that had given inconsistent reactions to an individual race in previous tests were rechecked under controlled temperature conditions. With the exception of a few entries that are of special interest, the 120 varieties and selections listed in Table 1 are the most resistant entries obtained from the world collection of barley.

The 16 varieties listed in Table 2 are those that have been crossed with the widely adapted

spring variety Manchuria (C.I. 2330)[2], and winter varieties Randolph (C.I. 6372) and Reno (C.I. 6561). Of the 16 varieties used, some were chosen because they had one gene for resistance to California race 3, while the other varieties were chosen because of their outstanding resistance as determined by field tests (14). Progenies from the original crosses that were homozygous for resistance to California race 3 are being backcrossed to the adapted varieties in order to obtain agronomically adapted lines with different genes for resistance.

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COOPERATIVE INVESTIGATION BETWEEN THE FIELD CROPS RESEARCH BRANCH, AGRICULTURAL RESEARCH SERVICE, UNITED STATES DEPARTMENT OF AGRICULTURE, AND THE NORTH CAROLINA STATE AGRICULTURAL EXPERIMENT STATION

# REACTION OF INBRED LINES OF CORN TO BROWN SPOT

P. H. Harvey, D. L. Thompson[1], and T. T. Hebert[2]

The brown spot disease of corn, caused by Physoderma maydis Miyabe, (Physoderma zeae-maydis Shaw) is frequently widespread in the Coastal Plain area of North Carolina. Reduced grain yields and broken stalks result from heavy infection during wet seasons. The development of resistant hybrids appears to be the most practical means of reducing these losses. Corn breeding lines from various sources were tested for reaction to brown spot by artificial inoculation in the field as a part of a breeding program to develop resistant hybrids.

Inoculum was prepared by grinding dried infected leaves and leaf sheaths from the previous year in a Wiley Mill. Approximately 100 cc of this ground tissue containing resting sporangia

Table 1/ Brown spot ratings on corn inbreds.

| Inbred | Origin | Rating[a] | | | |
|---|---|---|---|---|---|
| | | 1950 | 1951 | 1954 | Average |
| Ab 13 | Alabama | | 2 | | |
| C.I. 2A | USDA | 2 | | 2 | 2 |
| C.I. 3A | " | 2 | | 1 | 1.5 |
| C.I. 7 | " | 3 | | 3 | 3 |
| C.I. 14 | " | 5 | | 2 | 3.5 |
| C.I. 19 | " | | | 2 | |
| C.I. 21 | " | 5 | | 4 | 4.5 |
| C.I. 21E | " | | | 2 | |
| C.I. 27 | " | 2 | | 1 | 1.5 |
| F2 | Florida | 2 | | 1 | 1.5 |
| F3 | " | 4 | | 4 | 4 |
| F6 | " | 1 | | 2 | 1.5 |
| F44 | " | 1 | | 2 | 1.5 |
| Ga199 | Georgia | | 2 | | |
| GaB110 | " | | 3 | | |
| KIH201 | " | 3 | | | |
| GE4 | " | | 2 | | |
| GE11 | " | | 4 | | |
| GE12 | " | | 3 | | |
| GE17 | " | | 3 | 4 | 3.5 |
| GE195 | " | | 2 | 2 | 2 |
| GE205 | " | | 3 | 4 | 3.5 |
| GT3 | " | 4 | | 3 | 3.5 |
| GT7 | " | | | 4 | |
| GT106 | " | 5 | 3 | 3 | 3.7 |
| GT112 | " | 5 | | 5 | 5 |
| GT150 | " | | 1 | 2 | 1.5 |
| GT154 | " | 1 | | 1 | 1 |
| GT8950 | " | 1 | | 2 | 1.5 |

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was suspended in 2 1/2 gallons of water and screened to remove large fragments. Plants were inoculated when they were 1 to 3 feet tall by placing 5 to 10 cc of the sporangial suspension in the whorl of each plant using a 2 or 3 gallon sprayer from which the whorl plate of the nozzle had been removed. Inoculations were made at 10 to 14 day intervals. Three inoculations were made in 1950 and only two in 1951 and 1954.

Differences in symptom expression were noted in several inbred lines. NC 68, for example, showed numerous small yellow lesions on the leaf blade but did not develop typical brown spots on the midrib and sheath; whereas, NC 16 had brown lesions on the midrib and sheath but no lesions on the leaf blade. The most susceptible inbreds, such as NC 7, had numerous spots on all parts of the leaf.

The disease ratings (Table 1) were generally uniform from year to year. The most obvious

Table 1. Continued.

| Inbred | Origin | Rating[a] | | | |
|---|---|---|---|---|---|
| | | 1950 | 1951 | 1954 | Average |
| H25 | Indiana | 4 | | | |
| K4 | Kansas | 2 | | 3 | 2.5 |
| K64 | " | 3 | | | |
| K126 | " | 2 | | 3 | 2.5 |
| K148 | " | 1 | | | |
| K150 | " | 3 | | | |
| Kys | " | 3 | | 4 | 3.5 |
| Ky201 | Kentucky | | 2 | | |
| Ky30A-38-11 | " | | 3 | | |
| Ky36-11 | " | | 2 | | |
| Ky41-52 | " | | 2 | | |
| Ky41-79 | " | | 2 | | |
| Ky43-21 | " | | 4 | | |
| Ky43-24 | " | | 2 | | |
| Ky43-38 | " | | 2 | | |
| L87 | Louisiana | | | 2 | |
| L87-2 | " | | | 2 | |
| L90 | " | 2 | | 2 | 2 |
| L501-Y | " | 3 | | 3 | 3 |
| L568 | " | 3 | | | |
| L569 | " | 2 | | | |
| L578 | " | 2 | | 2 | 2 |
| L589-2 | " | 2 | | | |
| Mp303 | Mississippi | | 1 | | |
| Mp305 | " | | 1 | | |
| Mp307 | " | | 2 | 2 | 2 |
| Mp309 | " | | 2 | 3 | 2.5 |
| Mp311 | " | | 1 | | |
| Mp313 | " | | 2 | | |
| Mp315 | " | | 2 | 3 | 2.5 |
| Mp317 | " | | 2 | 4 | 3 |
| Mp406 | " | | 3 | | |

exceptions were NC 5, NC68, and C.I. 14. Several factors may have influenced the ratings in different seasons. Seasonal variations in moisture and temperature may have caused variation in the reaction of some inbreds. In addition, the rating was performed by different individuals each season, and the peculiar symptom expressions noted in certain lines added to the difficulty of rating.

Two inbreds, NC42 and GT 154, were very highly resistant to brown spot, showing only a trace in each year inoculated. Thirty of the other inbreds which were tested for two or more years had mean ratings of 2 or less. These lines are considered to be sufficiently resistant for use in a practical breeding program.

Table 1. Continued.

| Inbred | Origin | Rating[a] | | | |
|---|---|---|---|---|---|
| | | 1950 | 1951 | 1954 | Average |
| Mp410 | Mississippi | | 2 | 3 | 2.5 |
| Mp412 | " | | 1 | | |
| Mp414 | " | | 2 | 4 | 3 |
| Miss911 | " | | 1 | 2 | 1.5 |
| KLS28 | " | 3 | | | |
| KL65 | " | 5 | | | |
| KL85 | " | 5 | | | |
| N16 | Nebraska | 4 | | | |
| NC5 | North Carolina | 5 | 3 | 1 | 3 |
| NC7 | " " | 5 | | 5 | 5 |
| NC12 | " " | 5 | | 5 | 5 |
| NC13 | " " | 4 | | 3 | 3.5 |
| NC16 | " " | 4 | | 2 | 3 |
| NC18 | " " | 5 | | 5 | 5 |
| NC24 | " " | 3 | | 3 | 3 |
| NC33 | " " | 5 | | 4 | 4.5 |
| NC34 | " " | 2 | | 2 | 2 |
| NC37 | " " | 3 | | 2 | 2.5 |
| NC42 | " " | 1 | | 1 | 1 |
| NC45 | " " | 2 | | 2 | 2 |
| NC46 | " " | 4 | | 2 | 3 |
| NC52 | " " | 5 | | 5 | 5 |
| NC54 | " " | 5 | | 4 | 4.5 |
| NC61 | " " | 4 | | 3 | 3.5 |
| NC64 | " " | 2 | | 4 | 3 |
| NC65 | " " | 5 | | 4 | 4.5 |
| NC66 | " " | 2 | | 2 | 2 |
| NC67 | " " | 5 | | 3 | 4 |
| NC68 | " " | 4 | | 1 | 2.5 |
| NC69 | " " | 4 | | 4 | 4 |
| NC72 | " " | 3 | | 4 | 3.5 |
| NC74 | " " | 2 | 3 | 1 | 2 |
| NC75 | " " | 3 | 1 | 2 | 2 |

Table 1. Concluded.

| Inbred | Origin | Rating[a] | | | |
|---|---|---|---|---|---|
| | | 1950 | 1951 | 1954 | Average |
| NC76 | North Carolina | 4 | | 3 | 3.5 |
| NC77 | " " | 4 | 2 | 4 | 3.3 |
| NC78 | " " | 2 | 2 | 2 | 2 |
| NC81B | " " | 3 | 2 | 3 | 2.7 |
| NC82 | " " | 2 | 2 | 1 | 1.7 |
| NC83 | " " | 5 | | 3 | 4 |
| NC85 | " " | 5 | | | |
| NC86 | " " | 2 | 3 | 2 | 2.3 |
| NC87 | " " | 4 | 2 | 4 | 3.3 |
| NC88 | " " | | 3 | 2 | 2.5 |
| NC92 | " " | | 2 | 2 | 2 |
| Okl11 | Oklahoma | | 2 | | |
| T7 | Tennessee | 2 | | 1 | 1.5 |
| T8 | " | 2 | | 2 | 2 |
| T13 | " | 2 | | 1 | 1.5 |
| T61 | " | 2 | | 2 | 2 |
| T101 | " | 2 | | 2 | 2 |
| T105 | " | | | 3 | |
| T107 | " | | 4 | | |
| T109 | " | | 4 | | |
| T111 | " | | 2 | 3 | 2.5 |
| T113 | " | | 1 | | |
| T115 | " | | 1 | 2 | 1.5 |
| T204 | " | 2 | | 2 | 2 |
| T-J526-2 | " | 4 | | | |
| Tx61M | Texas | | | 2 | |
| Tx132A | " | 2 | | | |
| Tx173D | " | 5 | | | |
| Tx203 | " | 2 | | 2 | 2 |
| Tx341 | " | | 4 | | |
| Tx342 | Texas | | 2 | | |
| Tx343 | " | | 2 | | |
| Tx344 | " | | 4 | | |
| Tx401 | " | | 3 | 2 | 2.5 |
| Tx402 | " | | 2 | 3 | 2.5 |
| VI | Virginia | | 2 | | |

[a]Rating scale: 1 = highly resistant; 2 = resistant; 3 = intermediate; 4 = susceptible; 5 = very susceptible.

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# REMOVAL OF SPORES FROM MYCELIAL MATS AND TRANSMISSION OF ENDOCONIDIOPHORA FAGACEARUM BY AIR CURRENTS

E. A. Curl[1]

## ABSTRACT

Laboratory tests revealed that conidia of Endoconidiophora fagacearum were not readily removed from artificially and naturally grown mycelial mats by applied air currents. More conidia were removed from air-dried mats by air applied at a high velocity than from either air-dried or moist mats by air applied at lower velocities. More hyphal fragments and conidium-bearing conidiophores were removed than were free conidia. A few ascospores were removed from one naturally grown mat by air of high velocity.

In the field, conidia were trapped on agar plates located near 9 of 33 mycelial mats on wilt-killed oak trees.

The ability of wind-blown spores to infect small oak trees in nature was tested. Of 96 wounded trees subjected to air blown across naturally grown mats, 5 wilted and died.

## INTRODUCTION

Above-ground transmission of oak wilt has received considerable attention by a number of workers during the past three years. However, past studies have dealt almost entirely with transmission of the disease by insects. The natural habit of Endoconidiophora fagacearum to fruit beneath the bark and the sticky nature of the conidia and ascospores tend to lead to the assumption that dissemination of the fungus by air currents is improbable. The following work was conducted to investigate this improbability.

## LABORATORY TESTS

As a preliminary step in the investigation, several limited tests were conducted in the laboratory. In the first test, pieces of wood that measured approximately 2 by 3 inches by 1/2 inch and that emitted the strong amyl acetate odor characteristic of oak wilt were cut from a wilt-killed red oak. These were placed in moist chambers for 10 days, during which time dense conidium-bearing mycelial mats of E. fagacearum developed. To determine the natural facility of conidia to fall from mycelial mats, 2 pieces of the mat-bearing wood were inverted on ring stands at a distance of 6 inches and 2 pieces at a distance of 12 inches above open plates of water agar and open plates of chestnut agar. After exposure for 12 hours, the water agar plates were incubated for 36 hours and the chestnut agar plates for 7 days at 23° C. Examination revealed no germinated nor nongerminated conidia on the water agar and no colonies of E. fagacearum on the chestnut agar, indicating that no spores had fallen from the mats. A similar test, in which artificially grown mats were held above open plates of agar and tapped lightly several times, also gave negative results.

The removal of conidia from mats by applied air was tested in the laboratory. Artificial mycelial mats, like those described above, were placed 6 inches away from open plates, some of water agar and some of chestnut agar. Streams of air from a laboratory air-line were then directed by means of a short piece of rubber tubing across the conidium-bearing mats toward the open plates at 3 rates of flow, or "velocities," designated as "low", "medium," and "high." The rates of air flow were controlled by opening or closing the air-line valve. A different mat was used for each of the 2 media, and 1 plate of each medium was exposed to each air velocity. After exposure for 30 seconds all plates were incubated at 23° C. No colonies of E. fagacearum appeared on the chestnut agar plates, and no conidia were found on water agar plates exposed to low or medium air velocities. However, 10 germinated conidia were found on the plate of water agar that had been exposed to air of high velocity.

It is reasonable to assume that conidia will adhere with greater tenacity to the hyphae of

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Table 1. Average number of conidia, conidiophores, and hyphal fragments removed from artificially grown, moist and dry mycelial mats of Endoconidiophora fagacearum and deposited on plates of agar by air applied at 3 velocities.

| Condition of mats | Mat Number | Low velocity | | | Medium velocity | | | High velocity | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Free Conidia | Conidio-phores | Hyphal fragments | Free conidia | Conidio-phores | Hyphal fragments | Free conidia | Conidio-phores | Hyphal fragments |
| Moist | 1 | 0 | 0 | 0 | 0 | 1.0 | 2.0 | 0 | 3.0 | 45.0 |
| | 2 | 0 | 0 | 0 | 0 | 0 | 1.0 | 0 | 5.0 | 10.0 |
| | 3 | 0 | 0 | 0 | 0 | 0 | 1.0 | 0 | 6.0 | 65.0 |
| | 4 | 0 | 0 | 0 | 1.0 | 2.0 | 3.0 | 2.0 | 35.0 | 50.0 |
| | 5 | 0 | 0 | 1.0 | 0 | 0 | 18.0 | 0 | 0 | 180.0 |
| | 6 | 0 | 0 | 0 | 0 | 0 | 0.5 | 0 | 1.0 | 5.0 |
| Dry | 1 | 0 | 0.2 | 1.0 | 0 | 0.2 | 4.0 | 0.5 | 11.0 | 40.0 |
| | 2 | 0 | 0 | 1.2 | 0 | 0.5 | 4.0 | 0 | 1.0 | 13.0 |
| | 3 | 0 | 0.5 | 1.5 | 0 | 1.0 | 5.0 | 0 | 1.0 | 20.0 |
| | 4 | 0 | 0.5 | 2.0 | 0.5 | 0.5 | 30.0 | 2.0 | 2.5 | 80.0 |
| | 5 | 0 | 0.2 | 2.0 | 2.0 | 3.0 | 22.0 | 25.0 | 30.0 | 200.0 |
| | 6 | 0.5 | 3.0 | 20.0 | 10.0 | 15.0 | 60.0 | 20.0 | 35.0 | 230.0 |

fresh, moist mycelial mats than to hyphae of dry mats. It has been shown[2] that conidia of E. fagacearum may retain their viability for as long as 330 days when mats are allowed to become very dry at a low temperature. To test further the removal of conidia from mycelial mats by air currents, the following experiment was conducted. Pieces of wood measuring approximately 3 inches by 3/4 by 1/2 inch, taken from a red oak, were placed on end in 250-ml flasks that contained 75 ml. of chestnut broth (50 g dried chestnut meats in 1 liter of water). The pieces of wood and broth were then steam-sterilized, and the broth was seeded with the oak wilt fungus. After 2 weeks incubation at 25° C, each piece of wood was found to be covered by a dense mycelial mat. The mats contained an abundance of conidia. Half of these mats were removed from the flasks, wrapped in dry paper toweling, and stored at 22° C for 5 days. The other mats were left in the flasks and stored at 22° C during this period to be used later in their fresh, moist condition.

For further treatment of the mats the following apparatus was prepared. The large end of a short glass extraction tube was made fast, by means of grafting tape, to one end of a piece of glass tubing measuring approximately 12 inches in length and 1 1/2 inches in diameter. This gave a large glass tube about 18 inches in length that tapered to an opening of 6 mm in diameter. The bottom of a quart-size polyethylene bag was removed to make a sleeve, one end of which was fastened securely with grafting tape to the large end of the glass tube. Each of the artificial mycelial mats was placed, one mat at a time, inside the polyethylene sleeve. A small glass tube, which was attached to a rubber tube connected to the laboratory air-line, was then inserted in the sleeve and the sleeve fastened securely to it. At the other end of the apparatus an open plate of water agar was attached with adhesive tape to an iron ring on a ring stand. The small end of the extraction tube was placed, 1 inch from the agar surface, and aimed at small circles made with wax pencil on the bottom of the petri dish. Air was then applied across the mat at the other end at each of 3 velocities for 1 minute. One mat was used for each series of 3 velocities, and the agar above 5 circles in each plate was exposed to each velocity. These tests were replicated 6 times. The average numbers of free conidia, conidiophores, and hyphal fragments as seen in the low power field of a microscope were determined.

The results of this experiment are presented in Table 1. No conidia were removed from moist and very few from dry mats by air of low velocity. The average number of free conidia removed from moist mats by air of medium and high velocities was only slightly higher. However, the average number removed from dry mats by the last 2 velocities was considerably higher. Conidiophores, usually with chains of conidia attached, were removed in greater numbers than were conidia, and the hyphal fragments were removed in greater numbers than were either conidia or conidiophores.

A similar experiment was carried out in which fresh, naturally grown mycelial mats were used. Again, it was shown (Table 2) that medium and high air velocities removed conidia, conidiophores, and hyphal fragments from mats in larger numbers than did air of low velocity. A few ascospores also were removed by air of high velocity.

## FIELD EXPERIMENTS

During the period May 26-June 16, 1954, a study was made of the natural fall of spores from mycelial mats on wilt-killed oaks in Sinnissippi Forest in northern Illinois. Thirty-three mats of E. fagacearum on 4 large standing red oaks were selected for study. Only mats that emitted a strong characteristic amyl acetate odor from cracks in the bark were used. This odor is a good indication that mats beneath the bark have not started to deteriorate. The mats were located on the trees at heights of from 4 to 30 feet. Ladders of oak wood slabs nailed to the trunks and a lineman's safety belt facilitated examination of the fungus mats.

When a crack was located in the bark, beneath which a suitable mat was believed to be present, 4 large nails were driven into the wood, 2 on either side of the crack. Two other nails were driven into the wood approximately 2 1/2 inches apart directly below the crack. Two strips of adhesive tape were crossed, and the ends attached to the 4 nails first mentioned. Where the strips crossed, an open plate of 2% water agar was stuck to the tape so that the exposed agar surface faced the trunk of the tree at a distance of 3 inches from the center of the crack. Another open plate of agar was placed on the 2 nails below the crack and made secure with tape. When the plates had been exposed in these positions for 1 hour, they were removed and closed

[2] Curl, E. A. 1955. Natural availability of oak wilt inocula. Illinois Nat. Hist. Surv. Bul. 26(3): 277-323.

Table 2. Average number of conidia, conidiophores, and hyphal fragments removed from naturally grown mycelial mats of Endoconidiophora fagacearum and deposited on plates of agar by air applied at 3 velocities.

| Mat Number | Low velocity | | | Medium velocity | | | High velocity | | |
|---|---|---|---|---|---|---|---|---|---|
| | Conidia | Conidiophores | Hyphal fragments | Conidia | Conidiophores | Hyphal fragments | Conidia | Conidiophores | Hyphal fragments |
| 1 | 0 | 0 | 0 | 0 | 0 | 0.5 | 0 | 0 | 1.0 |
| 2 | 0 | 0 | 0 | 0 | 1.0 | 0 | 0.5 | 0 | 1.0 |
| 3[a] | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | 0 | 0 | 0 | 0 | 0 | 1.0 | 2.0 | 1.0 | 3.0 |
| 5[a] | 0 | 0 | 0 | 0 | 0 | 0 | 4.0[b] | 0 | 0 |
| 6 | 0 | 0 | 0 | 0 | 0 | 0 | 5.0 | 0 | 0 |
| 7 | 0 | 0 | 0 | 0 | 0 | 1.0 | 0 | 0 | 2.0 |
| 8 | 0 | 0 | 0 | 0 | 0 | 1.0 | 0 | 0 | 3.0 |
| 9 | 0 | 0 | 0 | 1.0 | 0 | 0 | 0 | 0 | 0 |
| 10[a] | 0 | 0 | 0 | 0 | 0 | 0 | 1.0 | 0 | 0 |
| 11[a] | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

a Mats with perithecia and ascospores.

b Ascospores and conidia.

Table 3. Number of germinated spores of Endoconidiophora fagacearum found in plates of water agar after exposure to air near naturally occurring mycelial mats.

| Mat Number | Condition of mat[a] | Concentration of conidia on mat | Perithecia present (+) absent (-) | Number of germinated spores found in plates for designated exposure positions | | | |
|---|---|---|---|---|---|---|---|
| | | | | In front of crack | Below crack | In front of exposed mat | Below exposed mat |
| 2 | M | Few | + | 0 | 2 | 0 | 0 |
| 9 | A | Abundant | + | 0 | 0 | 1 | 27 |
| 10 | A | Abundant | + | 0 | 0 | 6 | 250[b] |
| 11 | M | Abundant | + | 0 | 46 | 2 | 3 |
| 13 | M | Abundant | + | 0 | 11 | 0 | 9 |
| 15 | I | Abundant | - | 0 | 0 | 0 | 28 |
| 17 | M | Abundant | + | 0 | 0 | 0 | 3 |
| 20 | I | Abundant | - | 0 | 0 | 0 | 3 |
| 23 | A | Few | + | 0 | 0 | 15 | 0 |

[a] I = Immature; M = Mature; A = Aging.

[b] A small insect (Nitidulidae) had fallen into the plate and left a trail of ascospores, most of which germinated.

with the plate tops. A section of bark covering the mat was then removed with a sharp chisel, exposing the entire mat to the outside. At this time the condition of the mat was noted and ddsignated as immature, mature, or aging; the presence or absence of perithecia was recorded, and small samples of mycelium were taken with a cork borer for laboratory determination of the approximate concentration of conidia. Then, 2 more open plates of water agar were placed in position as before, 1 directly in front of and the other directly below the exposed mat, for a period of 1 hour. Other mats on the 4 selected trees were treated in this manner until a total of 132 plates of agar had been exposed. The wind velocity around the trees was estimated to range from low to moderately high during the experimental period. All plates were incubated in the laboratory at 25° C for 36 hours and examined through a microscope for germinating spores.

The results are presented in Table 3. Only mats near which spores were caught in plates are included in the table. More spores were caught on plates located below exposed mats than on plates located below cracks or directly in front of exposed mats. No spores were caught on plates located in front of undisturbed cracks in the bark. The 250 ascospores that were found in the plate below mat number 10 were carried there by an insect that fell from the mat. In plates other than the one contaminated by the insect, it was not possible to tell if the germinated spores were conidia or ascospores. However, of the 33 mats studied, 19 had numerous perithecia, and spores were caught on plates that were exposed to 7 mats with perithecia and 2 without.

Another experiment was conducted to determine the ability of wind-blown spores to infect wounded oak trees. The trees selected for the tests were red oaks ranging in size from 1/2 to 2 1/2 inches d.b.h. and located in one area in Sinnissippi Forest. The nearest oak wilt area where trees were producing mycelial mats was approximately 2 miles distant. Fresh mycelial mats of E. fagacearum were cut from wilt-killed oaks in several other areas in the forest and transported to the experimental area in polyethylene bags stored in a metal, iced picnic box. All mats were used within 24 hours after they were collected. The tests were made late in the afternoons of May 27 and 28 under very cloudy and humid conditions. With a sterilized hand ax, a deep slanting wound was made in the trunk of each of 96 trees about 2 feet from the ground. Immediately thereafter a mat was held about 3 inches from the wound, and 3 moderately strong blasts of air were blown by mouth across the surface of the mat toward the wound. Each mat was used to treat 5 trees. To serve as controls, 25 additional trees in the same area were wounded only. All wounds were left open and exposed to the air to more nearly simulate natural conditions.

Of the 96 trees treated, only 5 produced typical symptoms, wilted, and died. Three of these trees showed incipient wilt 33 days, one 20 days, and one 61 days after treatment. Three of the trees that wilted had been treated with mats bearing perithecia and conidia and 2 with mats that had only conidia. None of the wounded control trees developed wilt symptoms.

## DISCUSSION

The results of the foregoing tests indicate that transmission of the oak wilt fungus by wind-blown spores from naturally occurring mycelial mats to wounded healthy oak trees is possible. Also, the probability of short-distance spread by air currents under favorable conditions seems real, though it might not occur often.

In the spore-trapping field tests, some spores were caught on plates located directly below undisturbed cracks in the bark as well as near exposed mats. Oak wilt research workers know that mats of E. fagacearum in nature are often partially exposed to the elements by squirrels that gnaw away the bark and by natural sloughing of the bark as a result of pressure created by the subcortical pads or cushions of the fungus. During the period of the field test reported here the natural velocity of the surrounding air was mostly low or gentle to moderately high. It is reasonable to believe that, during storms accompanied by very strong winds, a much greater number of spores as well as conidiophores and hyphal fragments may be removed from mycelial mats. A few of these spores or hyphae might be deposited in wounds that are ever present on healthy oaks in the area. The transmission tests in the field showed that spores or vegetative parts of the fungus or both are capable of infecting and killing young oaks when these are blown into fresh wounds.

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# LONGEVITY OF PERIDERMIUM HARKNESSII AECIOSPORES STORED AT 40° F

Paul C. Lightle[1]

A search of the literature has revealed no data on longevity of spores of the various spore stages of the western gall rusts. Considerable information is available, however, on longevity of the aeciospores of white pine blister rust (4), and Siggers (3) found that occasional aeciospores of the fusiform rust, stored at a temperature below 10° C, were still viable 211 days after collection. In connection with experiments at the Institute of Forest Genetics on the resistance of ponderosa pine (Pinus ponderosa Laws.) to the western gall rust caused by Peridermium harknessii J. P. Moore (Cronartium coleosporioides (Diet. & Holw.) Arth.) rather large quantities of aeciospores were collected. Part were used to inoculate hybrid pine seedlings and the remainder were stored to test the length of time they would remain viable under known conditions at a uniform temperature. This note presents the results of the longevity tests.

## Materials and Methods

Ten to 20 sporulating galls were collected in May and June 1953, from living trees, and placed in a pollen-extraction funnel (1). The galls were allowed to sporulate for 3 to 5 days. During this period 40 to 50 cc. of spores were collected in glass vials. About 20 cc. of these were placed in separate sterile glass vials plugged with cotton. They were stored in a refrigerator at approximately 40° F. Before refrigeration, some were air-dried for 48 hours in the laboratory where the relative humidity was estimated to be 15 to 20 percent. Others were placed in a dessicator over calcium chloride and dried for an equivalent period.

For testing viability, a slight modification of Righter's (2) method for making germination tests on pine pollen was used. Small holes about 2 mm. in diameter, rather than squares, were punched through paraffin in the bottom of a petri dish, leaving about 1 cm. between holes. A drop of sterile distilled water was placed in each hole and a small amount of aeciospore material dusted on the surface. A small amount of water was placed in the inverted lid of the petri dish and the bottom, containing the test spores, was then inverted and placed in the lid. This gave an effective moist chamber in which spores could be germinated and the germination checked by a microscope.

## Result and Summary

Before storage the viability of the spores under all treatments was nearly 100 percent, and the color, viewed en masse, was bright orange. After 14 months the color had faded considerably but was still a little more orange than yellow. After 20 months, the color had faded to a rather dull yellow. The results of the viability tests are given in Table 1.

Table 1. Viability of Peridermium harknessii aeciospores with and without drying after storage for 14 to 20 months at 40° F.

| Treatment | Percentage of spores germinating after | | |
|---|---|---|---|
| | 0 months | 14 months | 20 months |
| Not dried | 100 | 5 | 0.5 |
| Air-dried | 99 | 15 | 1.0 |
| Dessicated | 98 | 1 | trace |

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Aeciospores, being thickwalled spores, are generally considered to be relatively long-lived. Table 1 confirms this. The data also indicate that, while the difference is not great, the final moisture content of the spores before storage had some effect on the longevity of the spores. The effect was more apparent at the end of 14 months storage than after 20 months. Under favorable storage conditions, the aeciospores of P. harknessii are capable of living over an entire year. That they do so in nature seems questionable.

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# FUNGICIDE TESTS FOR CONTROL OF CEDAR APPLE RUST ON HAWTHORN

R. J. Campana and I. R. Schneider

Although various chemicals have been reported for control of cedar rust fungi (Gymnosporangium juniperi-virginianae Schw. and G. globosum Farl.) on apple (Malus spp.) and cedar (Juniperus virginiana L.) (1, 2, 3, 4, 7, 8, 10, 11, 12, 13) relatively few have been tested specifically for control of rust on hawthorn (Crataegus spp.). With continued use of cedars and hawthorns in close proximity in mixed, ornamental plantings or near native populations of either alternate host, there is a need for detailed information on fungicides which may be suitable for more effective control of rust fungi on hawthorns.

For the past decade Fermate either alone or combined with sulfur has been considered the most effective material for control of rust on apple and hawthorn (4, 5). Reported to be unusually specific in toxicity to species of Gymnosporangium, Fermate, in addition, has been considered to have some nutritional value to pomaceous hosts of rust fungi. Hamilton et al. (4) found under certain conditions that sufficient fungicide was translocated in individual growing leaves and into adjacent unsprayed leaves to give protection against the rust fungus. However, for adequate control of rust infection, four to six successive spray applications over a 6- to 8-week period have been required. For individual ornamental hawthorns such an extensive spray schedule is both costly and laborious. Any fungicide requiring fewer spray applications with control comparable to that of Fermate-sulfur would make control more practical. Tests were undertaken in a search for new and more effective fungicides. Fermate with sulfur, as a single treatment, was used as a basis for comparison of the effectiveness of the fungicides tested (Table 2). Phygon and Tag 331 have been reported as effective in the control of rust on apple (5). The other fungicides have not previously been reported for rust control either on apple or hawthorn to the knowledge of the writers. In these trials no attempt was made to test the effectiveness of the fungicides over the whole period when leaf infection from rust spores may occur in nature. Rather, it was our purpose to evaluate the fungicides tested by bringing fungicides and fungus spores together on the host.

## Methods

Seventy hawthorns comprising both rough-leaved and smooth-leaved species in groups of ten were sprayed with one of seven fungicides (Table 2) and ten were left untreated. Fungicides were applied with a hand pack Hudson spray tank of two gallon capacity. All trees were 5 to 7 feet in height. The sprays were applied on April 9, 19, 28, May 5, and 20. On April 9 the smaller trees were either dormant or in the broken bud stage, and the larger ones were in the broken bud stage. On April 19 all trees were in the broken bud stage. On April 28 the trees varied from the broken bud condition to that of full flower or full leaf. On May 5 all trees had not reached full leaf expansion, although most had leafed out completely. On May 20 leaf development was complete.

At the beginning of the tests it was expected that cedar-apple galls, collected and hung on branches of the hawthorns, would provide sufficient inoculum to infect the hawthorn leaves without further manipulation. However, after detachment from the cedars, the galls dried as a result of the absence of cool and moist weather. Since there was no nearby source of inoculum for natural infection of hawthorn leaves by spores of Gymnosporangium juniperi-virginianae or G. globosum, a suspension of teliospores and basidiospores was prepared from the nearest source of galls. Following a heavy rain on May 19, 1954, 150 cedar-apple galls of G. juniperi-virginianae from 1 to 3 inches in diameter and with inflated telial horns were collected from infected cedars. The telial horns were stripped by hand from the galls, macerated into a pulp, washed with 2 gallons of tap water and strained through cheese cloth. The water extract contained a heavy suspension of both teliospores and basidiospores. The average count per field of basidiospores in five microscopic fields under high, dry power was 29. The suspension was diluted with water at a ratio of 1:1 and applied to the hawthorns on the day prepared with a hand pack Hudson sprayer. The spore suspension was applied on only one side of the trees because of the limited amount of inoculum, and on the north side because the wind was blowing from that direction at the time of inoculation. On July 14 ten terminal leaves of five branches on the north side selected at random from each tree were examined for pycnial lesions, and the average number of lesions per leaf was recorded (Table 2).

Table 1. Average number of lesions per leaf on smooth-leaved and rough-leaved hawthorns.

| Treatment | Smooth-leaved | | Rough-leaved | |
|---|---|---|---|---|
| | Numbers of trees | Lesions per leaf | Numbers of trees | Lesions per leaf |
| Fungicides applied | 25 | .01 | 45 | 0.82 |
| Untreated controls | 5 | .10 | 5 | 15.04 |
| Totals | 30 | | 50 | |

Table 2. Fungicides tested on rough-leaved hawthorns for control of cedar-apple rust

| Fungicides | Amount per 100 gallons of water | Numbers of trees treated | Average number of lesions per leaf | Percent of disease reduction |
|---|---|---|---|---|
| Tag 331 | 1/2 pt. | 7 | 0.08 | 99** |
| Calcium sulfamate plus B-1956 | 3/4 lb. | 7 | 0.16 | 99** |
| Emmi | 1/2 pt. | 9 | 0.34 | 97** |
| Vancide 51 plus Vancide sticker | 2 qts. | 5 | 0.90 | 94** |
| Phygon | 1 lb. | 6 | 1.05 | 93* |
| Fermate - sulphur | 1/2 lb. - 2 1/2 lbs. | 4 | 1.50 | 90 |
| Monsanto 4367 plus Tergitol 7 | 3/4 lb. | 7 | 1.73 | 88* |
| Untreated | | 5 | 15.04 | |

*Significant at the .05 level of probability.
**Significant at the .01 level of probability.

## Results

Direct inoculation of hawthorn leaves by spraying with a suspension of teliospores and basidiospores was highly successful. MacLachlan (6) succeeded in inoculating hawthorns by brushing on leaves a suspension of teliospores of G. globosum and enclosing the inoculated twigs in a celluloid cylinder. Apparently, inoculation by spraying with spore suspensions of G. juniperi-virginianae can be successful under moderate conditions of temperature and humidity without artificial protection from drying. Inoculation with an obligate parasite by such a method can be an effective technique in screening fungicides for control.

On June 14 pycnial lesions began to appear and by July 1 they were conspicuous and abundant. Infection of leaves of the smooth-leaved species of hawthorns was so slight that the data obtained were of no value for evaluating the effectiveness of the fungicides (Table 1). The data are presented here to show the difference in susceptibility between rough-leaved and smooth-leaved species of hawthorn. The average number of lesions per leaf on all smooth-leaved trees treated with fungicides was .01, and on the untreated controls it was .10; individual differences between fungicide treatments and the controls were not significant. Therefore only data for individual fungicide treatments on rough-leaved hawthorns is presented in Table 2. The ability

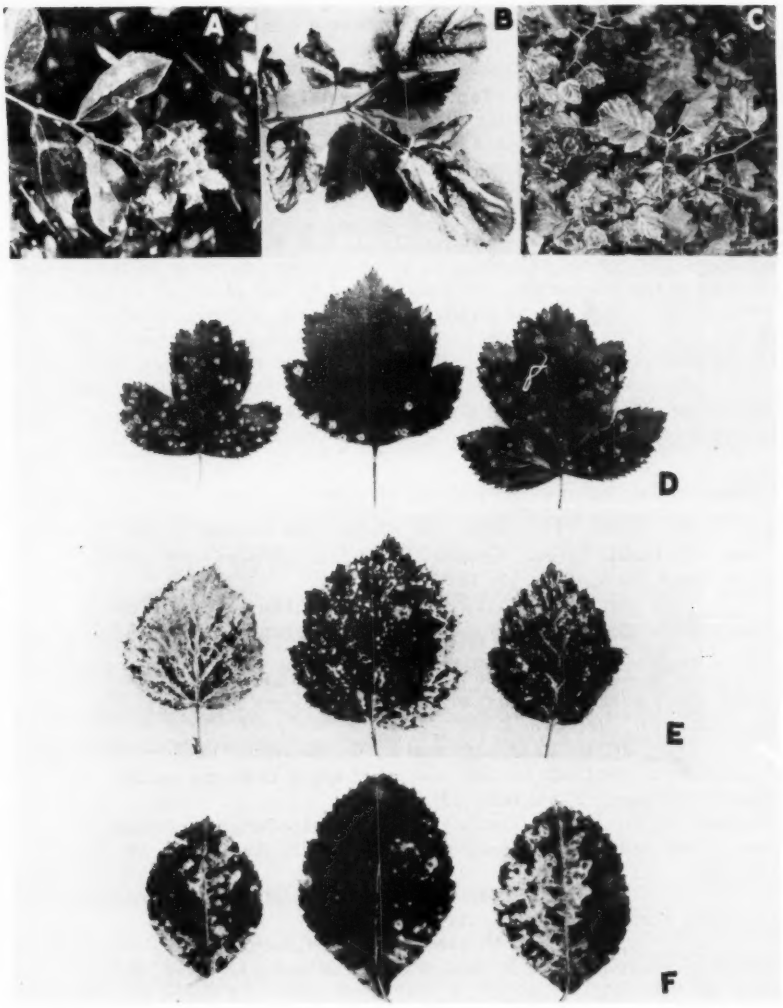


FIGURE 1. A, Twisting and curling of terminal foliage caused by M4367; B, cupping and interveinal chlorosis caused by calcium sulfamate; C, marginal burning and veinal chlorosis caused by M4367; D, pycnial infections of rust fungus on control artificially inoculated; E, injury caused by M4367 on rough-leaved hawthorns; F, injury caused by M4367 on smooth-leaved species.

of smooth-leaved hawthorns to resist rust infection by G. globosum has been reported by MacLachlan (5). The data in Table 1 show that they have a similar ability to resist infection by G. juniperi-virginianae.

All of the fungicide treatments except the treatment combining Fermate and sulfur reduced leaf infection to a significant degree (Table 2). Tag 331, calcium sulfamate, Emmi, Vancide 51, and Phygon were all significantly better than the control at the 1 percent level. Monsanto 4367 was significantly better at the 5 percent level. The Fermate-sulfur treatment probably would have been statistically significant also, if the number of trees treated had been greater. Tag 331, calcium sulfamate, and Emmi gave significantly better rust control than Fermate-sulfur, whereas Vancide 51 and Phygon did not.

Some of the chemicals used caused injury (Fig. 1, A, B, D, E, F). Tag 331, Emmi, and Vancide 51 caused some interveinal chlorosis on some species; calcium sulfamate and Monsanto 4367 caused severe marginal burning, withering, and killing of leaves of both smooth and rough-leaved hawthorns (Fig. 1, D, E, F), in addition to chlorosis; Phygon and Fermate-sulfur caused no injury. Of the fungicides tested, only calcium sulfamate and Monsanto 4367 caused sufficient injury to preclude their use for rust control on hawthorn at the dosages tested here. At lower dosages calcium sulfamate may possibly provide effective control without excessive phytotoxicity. Considering the effective control and relatively slight injury resulting from each, Tag 33 and Emmi showed promise as new materials for rust control on hawthorn.

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ILLINOIS STATE NATURAL HISTORY SURVEY, URBANA

## NEW AND UNUSUAL RECORDS OF PLANT DISEASES

### TAKE-ALL IN THE OLYMPIC NATIONAL PARK

By Roderick Sprague and P. M. Halisky[1]

Ophiobolus graminis Sacc. was found occurring under natural conditions in considerable quantity along a moist road cut near Lake Mills and in relatively dense coniferous woods at the foot of Hurricane Ridge Trail, Olympic National Park, July 23, 1955. This root-rot fungus was causing severe damage, especially to Bromus vulgaris (Hook.) Shear in the forest area. The leaves of this perennial host showed marked reddish-brown to yellowish pigmentation often to the very top of the plant. Many of the shorter plants failed to develop a panicle or produced only a sterile inflorescence, while others were dead. The bases of the culms were blackened with coarse, dark, mycelial wefts which developed under the leaf sheaths. Microscopic examination revealed numerous perithecia embedded in the sheaths of Bromus vulgaris (Hook.) Shear. These contained numerous mature asci with typical linear ascospores.

The fungus was observed on the following perennial hosts: Bromus vulgaris (Hook.) Shear[2], WSP 37468, 37470; Festuca subulata Trin., WSP 37469; Poa pratensis L., WSP 37472; Trisetum cernuum Trin., WSP 37474; and Luzula parviflora (Ehr.) Desv., WSP 37473; as well as on annual hairgrass, Deschampsia danthonioides (Trin.) Munro ex Benth., WSP 37471. Since the take-all fungus is apparently native in the Pacific Northwest, this wide host range occurring in one locality is not surprising.

Take-all was also seen on Bromus vulgaris (Hook.) Shear in second-growth woods west of Joyce, Washington in the general vicinity of the above-mentioned areas. In addition we observed take-all symptoms on dying Carex sp. associated with Trisetum, Luzula and Deschampsia along the moist road cut near Lake Mills in the Park area.

The courtesy of Park Officials in permitting the necessary collecting in the area is greatly appreciated.

STATE COLLEGE OF WASHINGTON, TREE FRUIT EXPERIMENT STATION, AND WASHINGTON STATE COLLEGE, DEPARTMENT OF PLANT PATHOLOGY

1 Plant Pathologist, State College of Washington, Tree Fruit Experiment Station and Research Assistant, Washington State College, Department of Plant Pathology, respectively.

2 Refers to accession numbers filed in Department of Plant Pathology Mycological Herbarium,, Pullman.

### OCCURRENCE OF THE CITRUS NEMATODE IN EGYPT

By Bakir A. Oteifa

Sour lemon trees, Citrus limonia Osbeck, 5 years old, growing in the region of Sinoris-Fauom, Egypt, were reported to be suffering from a malnutrition condition. Examination of the root system revealed that the fibrous feeding roots were severely infected with the citrus root nematode, Tylenchulus semi-penetrans Cobb, 1913.

This is the first record for the occurrence of this nematode in the citrus growing regions of Egypt. Experiments on the life cycle and methods of control of this nematode are under way.

PLANT PROTECTION DEPARTMENT, FACULTY OF AGRICULTURE, CAIRO UNIVERSITY, GIZA, EGYPT.

### THE OCCURRENCE OF PHOMOPSIS ON TOMATOES IN NEW YORK

By M. J. Ceponis and B. A. Friedman

In ripening studies at this laboratory, a small percentage of mature-green tomatoes from New City (Rockland County), New York, developed an extensive, soft, watersoaked decay. After holding in a moist chamber for several days at room temperature, there was a profuse development of pycnidia with pycnospores and stylospores typical of Phomopsis. Isolation and re-inoculation of mature-green and turning tomatoes with pure cultures of the organism revealed its pathogenicity.

There appears to be no previous report of the occurrence of Phomopsis sp. on tomatoes in New York State. A Phomopsis sp. reported to cause a fruit rot of tomatoes in Mississippi and

Texas, was referred to Diaporthe phaseolorum[1]. Luttrell found the disease in Georgia and reported the causative fungus as D. phaseolorum var. sojae[2]. Phomopsis sp. has also been observed in tomatoes from Hawaii[3].

U. S. MARKET PATHOLOGY LABORATORY, NEW YORK, NEW YORK

[1] Weiss, F., and M. J. O'Brien. 1953. Index of plant diseases in the United States. U. S. Dept. Agr. Plant Dis. Survey Spec. Pub. No. 1, Pt. 5. Cf. p. 1102-1103.

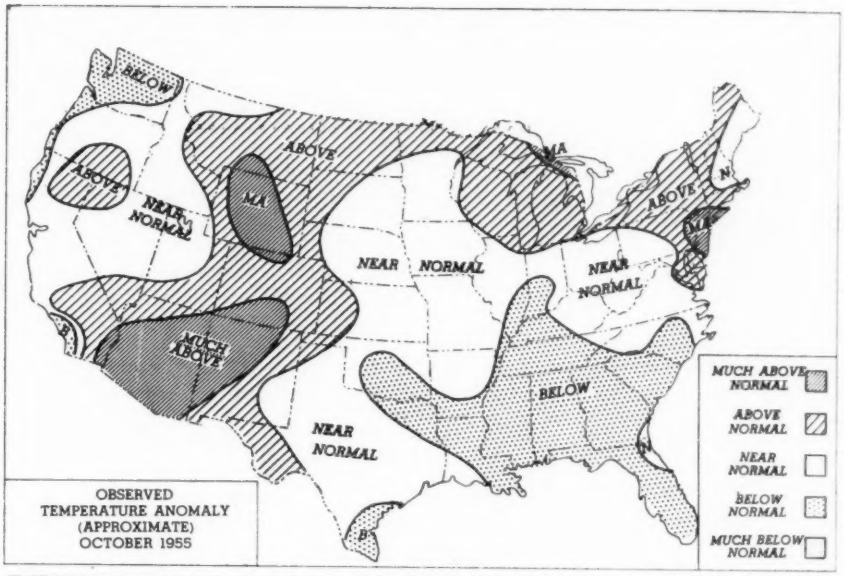
[2] Luttrell, E. S. 1947. Diaporthe phaseolorum var. sojae on crop plants. Phytopath. 37: 445-465.

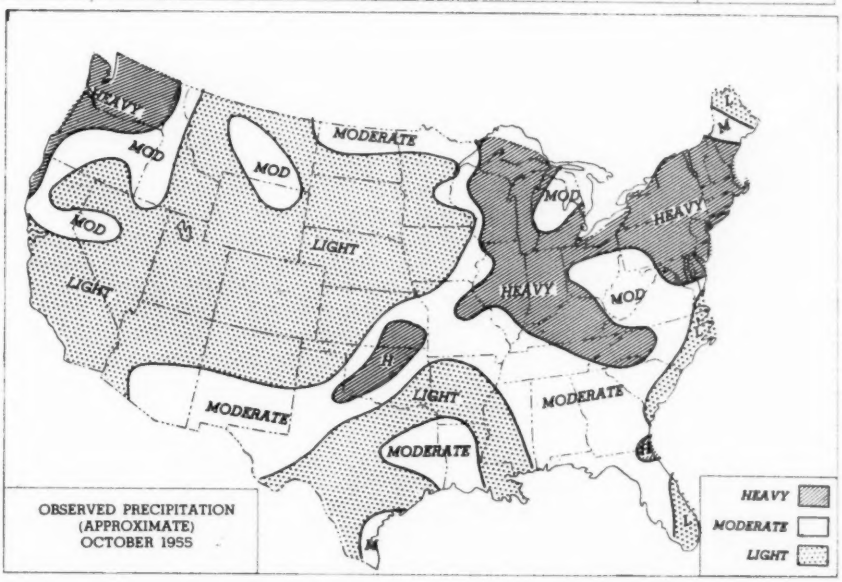
[3] Hendrix, J. W. 1950. A Phomopsis disease of tomatoes in Hawaii. (Abstr.) Phytopath. 40: 966.

## SOME CORRECTIONS

On page 105 of Plant Disease Reporter Supplement 233, issued October 15, 1955, the C.I. numbers should be corrected to read as follows: Hussar C.I. 4843, Loros C.I. 3779.

On page 802 of the November 15 issue, the fourth sentence of the second paragraph should read "The virus has a wide host range..." instead of "wide range."




**The terms used in the accompanying maps, which define the ranges of temperature and precipitation, are numerical class limits. These are based on a statistical analysis of past records through which is determined the normal frequency of occurrence of temperatures and precipitation at various times of the year for different locations. For temperature the classes above, below, and near normal are so defined that they each normally occur one-fourth of the time; much above and much below normal, one-eighth of the time Precipitation is depicted in terms of light, moderate, and heavy, each class normally occurring one-third of the time and thereby having equal probability of occurrence. These maps graphically represent only the general trends and give the country's weather picture at a glance. For quantitative studies, where monthly mean temperatures and actual precipitation records are needed for a given time and place, other publications of the Weather Bureau should be consulted. P. R. M.**

## MANUSCRIPTS FOR THE PLANT DISEASE REPORTER

(See also PDR 35: 121-122; 36: 214, 494)

(1) GENERAL: The Reporter page measures 9 inches long with the heading or 8 3/4 inches for the text part, by 6 inches wide. The copy is typed on a larger page, 11 1/4 inches of text or 12 inches overall in length by 8 inches in width, and reduced 25 percent in the photographic process of reproduction. Illustrations or tables larger in either dimension will take a correspondingly greater reduction. Only one size of type is available for text, footnotes, or tables.

(2) MANUSCRIPTS should be the original ribbon copy, not carbons, clearly typed and double-spaced throughout, including tables, footnotes, and bibliographies. (Note -- only one copy is needed.) Footnotes should be typed at the bottom of the page.

(3) ABSTRACTS are requested for all except very short articles. (PDR 38: 316).

(4) CAUSES OF DISEASES should be named. For bacteria, fungi, nematodes, etc., give the Latin name of the organism; for viruses either or both the accepted common name of the virus or a Latin name if you prefer it and there is one; for non-parasitic diseases state the causal factor if it is known. If the cause of a disease has not been determined say so. (PDR 36: 494).

(5) LITERATURE REFERENCES should be given in alphabetical order and numbered for citation in the text. We follow the AIBS suggestion of placing the year of publication after the author's name. Please check your titles carefully since we cannot do it for you. Be sure that text citations and bibliography agree; that foreign-language references are correct; that number or month is cited for periodicals that are not paged consecutively throughout the volume.

(6) NAMES OF FUNGICIDES should be given according to the suggestions that will be published in Phytopathology before long, and later repeated in the Reporter. In the meantime see PDR 35: 122.

(7) ILLUSTRATIONS should be sent to us unmounted. To prevent mistakes, write figure numbers on the back, and mark the top of each print when necessary. A sketch can show a preferred arrangement but please keep in mind page size, shape, and standard reduction (see above under General), and remember that figure titles and legends are part of the page. Lettering should be clear and large enough to be legible after reducing. Drawings, maps, and graphs can be photographs or originals, but should be finished and ready for reproduction, not just sketches.

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(9) REPRINTS cannot be supplied since there is no way in which we can be reimbursed. However,

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(11) We are the official correspondents in the United States of the PLANT PROTECTION BULLETIN published monthly by the United Nations Food and Agriculture Organization. We would appreciate it if plant pathologists would send us suitable material from time to time for inclusion in our monthly summary reports. Please mark it clearly so that we will know it is intended for the Bulletin. (See PDR 36: 492; 37: 637) -- P. R. M.